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THE MATHEMATICAL THEORY OF A NEW RELATIVITY

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CHAPTER X—The Perihelion of Mercury

CHAPTER XI—The Spectral Shift

CHAPTER XII—The Deflection of Light

Section I—Introductory

1. Newtonian Mechanics is supposed to have failed to satisfy the three tests indicated by the headings of these Chapters, while Einstein's General Theory of Relativity is believed to have been verified by them. The belief that light travels in space with a certain constant velocity was comprehensible. Lorentz had shown that certain mechanical and electromagnetic-optical phenomena could be explained by certain assumed transformations of co-ordinates called after his name. Einstein found that those transformations follow as a matter of course if one were to make the apparently impossible hypothesis of the constancy of the velocity of light not only in space but in all moving systems i.e. the velocity of light relative to a moving body is the same no matter what the velocity of that body be. This assumption was made inspite of the fact that the velocity of light is compounded with that of the earth to produce the aberration of stars. He characterised it as his great

principle regardless of the fact that time lost its absolute character. The assumption being approximately true gave good results for (a) Michelson and Morley's experiment, because the velocity of the Earth is small compared to that of light and (b) Bucherer's experiment, because the electric force acts normally to the path of the fast moving electron, and not tangentially. But not being rigorously true, it yielded only a fraction of the value for the perihelion of Mercury, because its orbit is elongated and its value is derived from observations extending over a large number of revolutions. He, therefore, had arbitrarily to assume the invariance of all physical laws with regard to co-ordinate transformation. The mathematical device is to make time as the fourth co-ordinate of a continuum, but as it is not commensurable with space, it had to be given an imaginary and unreal unit. Now we perceive the lapse of time not only by the change of position of a material body, but also by its change of state, particularly if it is a living organism. We know that after a certain lapse of time a child becomes a grown up lad. He has not merely altered his position in space but has changed in his state. By treating time as a fourth dimension of a continuum, and welding it into the three dimensions of space only one of its two attributes (viz. change of position with change of time) is taken into account, while the other (viz. change of state with change of time) is altogether ignored. It is really the ignored attribute which demonstrates that time is absolute and independent of space. Similarly, one may not be able actually to observe two *simultaneous* events, but such events do happen. While the earth is revolving round the moving Sun, do not the two bodies occupy some definite positions in their orbits at some particular specified time, even though we may not be able to observe the positions exactly? If they do, then their occupying such positions are two simultaneous events though not observed by man. Or do not living organisms exist simultaneously on this Earth? Again sequence of events in point of time can not be denied. Can any observer ever see the old age of a living person precede his childhood? If "rest mass" has to be conceded, which is nothing but absolute mass, then absolute time is the time of the observer with rest mass.

The fact is that the existence of natural phenomena is not dependent on the observation of man. So also time passes whether observed by man or not. It existed before man was born, and shall exist even if the human race becomes extinct. Time is really absolute and independent of Space.

2. The object of the New Relativity Theory is twofold. First, to show that *the velocity of gravitational influence is equal to that of light*, and therefore there are numerous corrections to be made which have so far been ignored, and that until they all have been introduced, it is impossible to say that Newtonian principles have failed. Secondly, that when the evidence is critically examined the claim generally put forward *that Einstein's Relativity has been verified is really unfounded*. Hence there is no necessity for accepting its unconvincing postulates. Chapters I, VIII and XIII with the Appendices show how corrections become necessary in Newtonian Mechanics. But the mathematical difficulty in taking all of them into account is great. Chapter II and the article in Science and Culture (Vol. I, Jan. 1936) containing an abstract of Chapters X, XI and XII, showed that the General Theory of Relativity has not only been not verified, but has been positively disproved. The calculated value of the advance of the perihelion of Mercury is unreliable. The observed value of the deflection of light is in excess of Einstein's value by at least one-third, while the spectral shift of light from the edge is double of Einstein's value. Fortunately a total Solar eclipse occurred this year on the 19th June and another will occur next year on the 8th June. The results of the observations when announced will throw further light on these crucial tests. These Chapters are accordingly held over for the present.

In the meantime the New Theory PREDICTS that light is governed by the same law of gravitation as a material particle, and that

(a) THE SPECTRAL SHIFT OF LIGHT FROM THE EDGE OF THE SUN IS DOUBLE OF ENISTEIN'S VALUE, WITH A GRADUAL VARIATION FROM THE CENTRE TO THE EDGE and

(b) THE DEFLECTION OF LIGHT FROM STARS PAST THE SUN LIES BETWEEN $4/3$ AND $3/2$ TIMES EINSTEIN'S VALUE AND IS MUCH NEARER TO THE LATTER THAN THE FORMER.

I must express my deep gratitude to Dr. D. S. Kothari, M. Sc., Ph. D., Reader in Physics at the Delhi University, for his great kindness in making many valuable suggestions, and also to Mr. Ram Niwas Rai M. Sc., Lecturer in Physics at the Allahabad University who has kindly given me the benefit of his opinions on the Rotational Mechanics contained in Ch. XIV,

CHAPTER XIII

Gravitation.

SECTION 1

Space-time Continuum-A Misinterpretation

1. Newton had supposed that gravitation acted instantaneously, which, in other words, meant that its velocity was infinite. Laplace considered the finiteness of the velocity of gravitational force, but came to a wrong conclusion as to its direction, and had to reject it as it caused too large disturbances in the elements of the planetary orbits. As his assumption led to a retardation of the motion, he could not utilise the existence of any resisting medium. In Einstein's Relativity the velocity of gravitation is utterly meaningless, as its value depends merely on a particular choice of co-ordinates.

In the present Theory the sole assumption made is that *the velocity of gravitational influence is finite*, but, unlike Laplace's deduction, the velocity must be from the attracting body towards the attracted body. As a statical effect is but the limiting case of a wave propagation when the frequency is very large, gravitational influence can be taken as a spherical wave propagation.

2. It can be easily seen that the welding of time and space into a four dimensional continuum is a mere mathematical device for misinterpreting a spherical wave propagation.

$$\begin{aligned} \text{Consider } \frac{\partial^2 V}{\partial t^2} &= D \left(\frac{\partial^2 V}{\partial x^2} + \frac{\partial^2 V}{\partial y^2} + \frac{\partial^2 V}{\partial z^2} \right) \\ &= \frac{D^2}{r^2} \frac{\partial}{\partial r} \left(r^2 \frac{\partial V}{\partial r} \right) \end{aligned}$$

where V is a function of r only.

This can be transformed into

$$\frac{\partial^2(rV)}{\partial(Dt)^2} = \frac{\partial^2(rV)}{\partial r^2}$$

The solution is $rV = f(r - Dt) + F(r + Dt)$,

The value of V at any instant over a sphere of radius r depends upon its values at a time t previous, over two spheres of radii $(r-Dt)$ and $(r+Dt)$. This shows that the motion is made up of two systems of spherical waves travelling outwards and inwards with velocity D .

(Lamb's Hydrodynamics, § 281).

$$\text{Hence } \frac{\partial^2 V}{\partial x^2} + \frac{\partial^2 V}{\partial y^2} + \frac{\partial^2 V}{\partial z^2} - \frac{1}{D^2} \frac{\partial^2 V}{\partial t^2} = 0 \dots \dots \dots \quad (40.1)$$

$$\text{and } dx^2 + dy^2 + dz^2 - D^2 dt^2 = 0$$

are equations of a spherical wave propagation in absolute space and absolute time.

Now there is a well known device in Vector analysis by which a real length when multiplied by the imaginary factor $\sqrt{-1}$ is taken to represent the same length rotated through 90° . If we apply the same device to the absolute time, and multiplying it by the same imaginary factor deprive it of its real character and evolve an incomprehensibly unreal co-ordinate we can transform the equation of a real wave propagation into one of an incomprehensible continuum of four dimensions.

Substituting $\omega = \sqrt{-1} \cdot Dt$ in the above equation, we get

$$\frac{\partial^2 V}{\partial x^2} + \frac{\partial^2 V}{\partial y^2} + \frac{\partial^2 V}{\partial z^2} + \frac{\partial^2 V}{\partial \omega^2} = 0 \dots \dots \dots \quad (40.2)$$

$$\text{and } dx^2 + dy^2 + dz^2 + d\omega^2 = 0$$

This is satisfied by functions with real exponents in the theory of probability, representing a wave of probability. These artificial four dimensional equations are nothing but a misinterpretation of a real spherical wave propagation in absolute three dimensional space and absolute real time.

3. For a trajectory in a nongravitational field

$$\begin{aligned} v^2 dt^2 &= dx^2 + dy^2 + dz^2 \\ \text{or } \left(1 - \frac{v^2}{D^2} \right) D^2 dt^2 &= D^2 dt^2 - dx^2 - dy^2 - dz^2 \dots \dots \dots \quad (40.3) \end{aligned}$$

$$\text{But Einstein has assumed } ds^2 = \left(1 - \frac{v^2}{D^2} \right) D^2 dt^2 = \Sigma g_{\mu\nu} dx_\mu dx_\nu \dots \quad (40.4)$$

The postulate that this ds^2 will have the general form under gravitational influence, where g's are functions of the variable t as well is fallacious. In reality, if only three variables x, y, z are transformed the g's are independent of time. The element ds^2 is the difference of the squares of the distances travelled by the gravitational wave, and by the body unaffected by gravitation, during a short interval dt . It has no other physical meaning. To keep ds real, two postulates become necessary.

$$(1) \ ds = 0 \text{ for light, as } v = D$$

$$\text{and} \quad (2) \ v \text{ cannot be greater than } D.$$

This substitution of the interval ds for the time interval dt lands us in an unreal four-dimensional world.

SECTION II

Spherical Wave Propagation

1. As gravitational influence spreads outwards equally in all directions, it behaves like the propagation of spherical waves, for which the equations already mentioned are

$$\frac{\partial^2 V}{\partial x^2} + \frac{\partial^2 V}{\partial y^2} + \frac{\partial^2 V}{\partial z^2} - \frac{1}{D^2} \frac{\partial^2 V}{\partial t^2} = 0$$

$$\text{Also} \quad dx^2 + dy^2 + dz^2 - D^2 dt^2 = 0$$

These equations are not symmetrical as the fourth terms are negative and also have extra coefficients. Making the purely artificial substitution $-D^2 dt^2 = dw^2$, we get

$$\frac{\partial^2 V}{\partial x^2} + \frac{\partial^2 V}{\partial y^2} + \frac{\partial^2 V}{\partial z^2} + \frac{\partial^2 V}{\partial w^2} = 0$$

$$\text{and} \quad dx^2 + dy^2 + dz^2 + dw^2 = 0$$

Now these equations are perfectly symmetrical with regard to the four variables x, y, z and w, which are therefore interchangeable inter se. Three out of these four are independent. As by a suitable choice of coordinates dx, dy, dy, dz, dz, dw and dw, dx can be made to vanish, it follows that Xdx^2 , Ydy^2 , Zdz^2 and Wdw^2 can represent the small changes introduced by this perfectly symmetrical influence, where the coefficients X, Y, Z and W must all be perfectly symmetrical with regard to the four variables x, y, z and w,

Hence if the elements of a particle unaffected by gravitation would in time dt at any point have been

$$\begin{aligned} & dx^2, dy^2, dz^2, -v^2 dt^2 \\ \text{or } & dx^2, dy^2, dz^2, \frac{v^2}{D^2} dw^2 \end{aligned}$$

where v is the momentary velocity, then its elements as accelerated by the gravitational force at that point will be

$$(1+X) dx^2, (1+Y) dy^2, (1+Z) dz^2, \left(\frac{v^2}{D^2} + W\right) dw^2,$$

where X, Y, Z and W are symmetrical functions of the four variables.

2. For the sake of facility we may write down the transformed wave equations as

$$\frac{\partial^2 V}{\partial x_1^2} + \frac{\partial^2 V}{\partial x_2^2} + \frac{\partial^2 V}{\partial x_3^2} + \frac{\partial^2 V}{\partial x_4^2} = 0 \dots \quad \dots \quad \dots \quad \dots \quad (40.5)$$

$$dx_1^2 + dx_2^2 + dx_3^2 + dx_4^2 = 0 \dots \quad \dots \quad \dots \quad \dots \quad (40.6)$$

Now neglecting small terms containing the products of three or more differentials, the most general form of the effect produced by the gravitational wave is

$$\begin{aligned} ds^2 = & g_{11} dx_1^2 + g_{12} dx_1 dx_2 + g_{13} dx_1 dx_3 + g_{14} dx_1 dx_4 \\ & + g_{22} dx_2^2 + g_{23} dx_2 dx_3 + g_{24} dx_2 dx_4 + g_{32} dx_3 dx_2 \\ & + g_{33} dx_3^2 + g_{34} dx_3 dx_4 + g_{31} dx_3 dx_1 + g_{32} dx_3 dx_2 \\ & + g_{42} dx_4^2 + g_{41} dx_4 dx_1 + g_{42} dx_4 dx_2 + g_{43} dx_4 dx_3 \dots \dots \quad (40.7) \end{aligned}$$

In this, six combinations overlap, so that we need have only ten g 's in the form $\sum g_{\mu\nu} dx_\mu dx_\nu$, where the g 's are symmetrical functions of the four variables x_1, x_2, x_3 and x_4 and their combinations can be written as

$$\begin{array}{cccc} g_{11} & g_{12} & g_{13} & g_{14} \\ g_{21} & g_{22} & g_{23} & g_{24} \\ & g_{31} & g_{32} & g_{33} \\ & & g_{41} & g_{42} \\ & & & g_{44} \end{array}$$

Take the change introduced by the gravitational field into the motion in the most general form $ds^2 = \sum g_{\mu\nu} dx_\mu dx_\nu$, where the

g 's are functions of the four variables, and not their differentials. The products of the three or more differentials have been neglected as they would be too small.

Here ds is the same for a material particle and for a light corpuscle as it represents the gravitational effect of the field. It is not zero anywhere except at ∞ . It is not necessary to define ds more exactly, as it will be ultimately eliminated.

Now the equation of the path of a particle, not affected by gravitation, would be $v^2 dt^2 - dx^2 - dy^2 - dz^2 = 0$

In a short interval dt , the velocity v , unaffected by gravitation, will remain constant. Hence the most general form when x, y, z only are transformed is

$$\sum a_{\mu\nu} dx_\mu dx_\nu = 0 \text{ where all the } a\text{'s are constants}$$

with regard to time. Therefore the equation of the trajectory in the gravitational field will be obtained by simply superposing the gravitational effect on this motion as $ds^2 = \sum (g_{\mu\nu} + a_{\mu\nu}) dx_\mu dx_\nu \dots \dots \dots \dots \quad (40.8)$

But as the effect ds^2 is perfectly symmetrical with regard to the four variables and is real, the expression on the right must be an invariant. Now $G_{\mu\nu} = 0$ gives the values of the g 's, which determine the geometry. $\dots \dots \dots \quad (40.9)$

If by a suitable choice of coordinates, the products of the differentials, except their squares, vanish in the original equation, they must also vanish in the transformed equation obtained by substitutions for only three out of the four variables. Hence the equation will retain the same form.

As the trajectory must be in a plane, and from the symmetry round the origin the coefficients should be independent of θ , we can take the equation in polar coordinates as

$$ds^2 = g_{11} D^2 dt^2 + g_{22} dr^2 + g_{33} r^2 d\theta^2$$

$$\text{or by transformation } = e^\nu D^2 dt^2 - e^\lambda dr^2 - r^2 d\theta^2 \dots \dots \dots \quad (40.10)$$

where ν and λ are some functions of r only.

Following the method (purely mathematical) used by Eddington in his Relativity, paragraph § 38 (pp. 83-5) we deduce that

$$\lambda = -\nu \text{ Putting } e^\nu = \gamma, \text{ we get } \gamma + \frac{d\gamma}{dr} = 1 \dots \dots \quad (40.11)$$

and therefore $\gamma = 1 - \frac{2\mu}{D^2 r}$, where 2μ is a constant of

integration. Hence $ds^2 = \gamma D^2 dt^2 + \frac{1}{\gamma} dr^2 - r^2 d\theta^2 \dots \dots \dots \quad (40.12)$

Proceeding as in § 39 (pp. 85-6), we get

$$\left. \begin{aligned} \frac{d^2\theta}{ds^2} + \frac{2}{r} \frac{dr}{ds} \frac{d\theta}{ds} &= 0 \\ \frac{d^2t}{ds^2} + \frac{dv}{dr} \frac{dr}{ds} \frac{dt}{ds} &= 0 \end{aligned} \right\} \dots \dots \dots \quad (40.13)$$

These two on integration give $r^2 \frac{d\theta}{ds} = \frac{h}{D}$

$$\text{and } D \frac{dt}{ds} = A e^{-v} = \frac{A}{\gamma} \quad \left. \right\} \dots \dots \dots \quad (40.14)$$

where h and A are constants

Eliminating ds and dt we get

$$\frac{1}{\gamma} \left(\frac{h}{Dr^2} \frac{dr}{d\theta} \right)^2 + \frac{h^2}{D^2 r^2} - \frac{A^2}{\gamma} = -1 \dots \dots \dots \quad (40.15)$$

substituting the value of γ we get

$$\left(\frac{1}{r^2} \frac{dr}{d\theta} \right)^2 + \frac{1}{r^2} = \frac{(A^2 - 1)D^2}{h^2} + \frac{2\mu}{h^2 r} + \frac{2\mu}{D^2 r^3}$$

$$\begin{aligned} \text{or } \left(\frac{du}{d\theta} \right)^2 + u^2 &= \frac{(A^2 - 1)D^2}{h^2} + \frac{2\mu}{h^2 u} + \frac{2\mu}{D^2} u^3 \\ \therefore \frac{d^2u}{d\theta^2} + u &= \frac{\mu}{h^2} + \frac{3\mu}{D^2} u^2 \quad \dots \dots \dots \quad (40.16) \end{aligned}$$

This is the equation of motion both for light and matter.

3. A simpler method is as follows:—

The equation for motion of the particle, unaffected by gravitation, in a plane is $dx^2 + dy^2 - v^2 dt^2 = 0$

where v is the initial velocity at the point (x, y) , unaffected by gravitation. Suppose that as a result of the gravitational influence during the short interval dt , in which v the initial velocity is constant, the equation becomes

$$(1 + P) dx^2 + (1 + Q) dy^2 + (R - \frac{v^2}{D^2}) D^2 dt^2 = 0$$

where P, Q and R may be some symmetrical functions of x, y and t.

Let us transform only two of these three variables by putting

$$x = r \cos\theta \text{ and } y = r \sin\theta$$

then the equation becomes

$$(1 + P \cos^2\theta + Q \sin^2\theta) dr^2 + (1 + P \sin^2\theta + Q \cos^2\theta) r^2 d\theta^2 + 2(Q - P) r \sin\theta \cos\theta dr d\theta \\ + (R - \frac{v^2}{D^2}) dt^2 = 0$$

where P, Q and R are now symmetrical functions of $r \cos\theta$, $r \sin\theta$ and $i D t$. For this to be symmetrical with respect to the three variables the coefficient of $dr d\theta$ must be zero, as other products do not occur. Hence $Q = P$. Therefore the equation takes the form

$$(1 + P) dr^2 + (1 + P) r^2 d\theta^2 + (R - \frac{v^2}{D^2}) D^2 dt^2 = 0$$

Here on account of symmetry and as a particular and simple case R can be equal to P, but can not be equal to -P, for that would make the gravitational effect vanish which it does not except at ∞ .

Now (1) from the symmetry round the origin, these coefficients must be independent of θ .

(2) as the source is not varying with time, and in the wave expansion t depends on r , these must be functions of r only.

(3) Also as the effect must be zero at ∞ , the coefficients when

$$\text{expanded give } P = \sum_1^{\infty} \frac{A_n}{r^n} \text{ and } R = \sum_1^{\infty} \frac{B_n}{r^n}$$

where the A's and B's are constants and are known to be small.

$$\text{Therefore } (1 + \sum_1^{\infty} \frac{A_n}{r^n}) dr^2 + (1 + \sum_1^{\infty} \frac{A_n}{r^n}) r^2 d\theta^2 + (\sum_1^{\infty} \frac{B_n}{r^n} - \frac{v^2}{D^2}) D^2 dt^2 = 0$$

Substituting $r^2 \frac{d\theta}{dt} = h$ nearly, we get (40.17)

$$(1 + \frac{A_1}{r} + \frac{A_2}{r^2} + \dots) dr^2 + (1 + \frac{A_1}{r} + \frac{A_2}{r^2} + \dots) r^2 d\theta^2 \\ + \left(\frac{B_1}{r} + \frac{B_2}{r^2} + \dots - \frac{v^2}{D^2} \right) \frac{D^2 r^4 d\theta^2}{h^2} = 0 \quad \dots \quad \dots \quad \dots \quad \dots \quad (40.18)$$

But for the orbits of the planets and comets and of light round the Sun, both r and h are very large and h is comparable to rD . And so

as an approximation terms up to $\frac{1}{r^3}$ and $\frac{D^2}{h^2} \frac{1}{r}$ only need be

$$\text{retained. Hence } \left(\frac{dr}{r^2 d\theta}\right)^2 + \left(1 + \frac{A_1}{r}\right) \frac{1}{r^2} = \frac{v^2}{h^2} - \frac{D^2 B_1}{h^2} \frac{1}{r}$$

$$\text{or } \left(\frac{du}{d\theta}\right)^2 + \left(1 + A_1 u\right) u^2 = \frac{v^2}{h^2} - \frac{D^2 B_1}{h^2} u$$

$$\begin{aligned} \text{Therefore } \frac{d^2 u}{d\theta^2} + u &= -\frac{D^2 B_1}{2h^2} - \frac{3A_1}{2} u^2 \\ &= -\frac{GM}{h^2} + k \frac{3GM}{D^2} u^2 \end{aligned}$$

where M is the mass of the gravitating body, and $G = -\frac{D^2 B_1}{2M}$

a gravitational constant, and k is some other constant.

As the simplest case, $R = P$ and therefore $A_1 = B_1$, hence $k = 1$.

But even if we do not assume that as the simplest particular case $R = P$, it is known from the advance of the perihelion of Mercury that $k = 1$.

$$\text{Hence } \frac{d^2 u}{d\theta^2} + u = \frac{\mu}{h^2} + \frac{3\mu}{D^2} u^2 \quad \dots\dots\dots(40.19)$$

This can be transformed into

$$\frac{d^2 r}{dt^2} - r \left(\frac{d\theta}{dt}\right)^2 = -\frac{\mu}{r^2} - \frac{3\mu h^2}{D^2} \frac{1}{r^4} \quad \dots\dots\dots(40.20.)$$

In this law of gravitational attraction the inverse cube of the distance does not occur.

4. Even in Einstein's Relativity, as ds and dt are ultimately eliminated, the equation of the orbit should be the same for a material particle as well as a light corpuscle, and the constant of integration h should remain finite for the velocity of light also,

But for the orbits of the planets and comets and of light round the Sun, both r and h are very large and h is comparable to rD . And so

as an approximation terms up to $\frac{1}{r^3}$ and $\frac{D^2}{h^2} \frac{1}{r}$ only need be

$$\text{retained. Hence } \left(\frac{dr}{r^2 d\theta}\right)^2 + \left(1 + \frac{A_1}{r}\right) \frac{1}{r^2} = \frac{v^2}{h^2} - \frac{D^2 B_1}{h^2} \frac{1}{r}$$

$$\text{or } \left(\frac{du}{d\theta}\right)^2 + (1 + A_1 u) u^2 = \frac{v^2}{h^2} - \frac{D^2 B_1}{h^2} u$$

$$\text{Therefore } \frac{d^2 u}{d\theta^2} + u = -\frac{D^2 B_1}{2h^2} - \frac{3A_1}{2} u^2$$

$$= \frac{GM}{h^2} + k \frac{3GM}{D^2} u^2$$

$$\text{where } M \text{ is the mass of the gravitating body, and } G = -\frac{D^2 B_1}{2M}$$

a gravitational constant, and k is some other constant.

As the simplest case, $R=P$ and therefore $A_1=B_1$, hence $k=1$.

But even if we do not assume that as the simplest particular case $R=P$, it is known from the advance of the perihelion of Mercury that $k=1$.

$$\text{Hence } \frac{d^2 u}{d\theta^2} + u = \frac{\mu}{h^2} + \frac{3\mu}{D^2} u^2 \quad \dots \dots \quad (40.19)$$

This can be transformed into

$$\frac{d^2 r}{dt^2} - r \left(\frac{d\theta}{dt}\right)^2 = -\frac{\mu}{r^2} - \frac{3\mu h^2}{D^2} \cdot \frac{1}{r^4} \quad \dots \dots \quad (40.20.)$$

In this law of gravitational attraction the inverse cube of the distance does not occur.

4. Even in Einstein's Relativity, as ds and dt are ultimately eliminated, the equation of the orbit should be the same for a material particle as well as a light corpuscle, and the constant of integration h should remain finite for the velocity of light also,

But for the orbits of the planets and comets and of light round the Sun, both r and h are very large and h is comparable to rD . And so

as an approximation terms up to $\frac{1}{r^3}$ and $\frac{D^2}{h^2} \frac{1}{r}$ only need be

$$\text{retained. Hence } \left(\frac{dr}{r^2 d\theta}\right)^2 + \left(1 + \frac{A_1}{r}\right) \frac{1}{r^2} = \frac{v^2}{h^2} - \frac{D^2 B_1}{h^2} \frac{1}{r}$$

$$\text{or } \left(\frac{du}{d\theta}\right)^2 + (1 + A_1 u) u^2 = \frac{v^2}{h^2} - \frac{D^2 B_1}{h^2} u$$

$$\text{Therefore } \frac{d^2 u}{d\theta^2} + u = -\frac{D^2 B_1}{2h^2} - \frac{3A_1}{2} u^2$$

$$= \frac{GM}{h^2} + k \frac{3GM}{D^2} u^2$$

where M is the mass of the gravitating body, and $G = -\frac{D^2 B_1}{2M}$

a gravitational constant, and k is some other constant.

As the simplest case, $R = P$ and therefore $A_1 = B_1$, hence $k = 1$.

But even if we do not assume that as the simplest particular case $R = P$, it is known from the advance of the perihelion of Mercury that $k = 1$.

$$\text{Hence } \frac{d^2 u}{d\theta^2} + u = \frac{\mu}{h^2} + \frac{3\mu}{D^2} u^2 \quad \dots\dots(40.19)$$

This can be transformed into

$$\frac{d^2 r}{dt^2} - r \left(\frac{d\theta}{dt}\right)^2 = -\frac{\mu}{r^2} - \frac{3\mu h^2}{D^2} \frac{1}{r^4} \quad \dots\dots(40.20.)$$

In this law of gravitational attraction the inverse cube of the distance does not occur.

4. Even in Einstein's Relativity, as ds and dt are ultimately eliminated, the equation of the orbit should be the same for a material particle as well as a light corpuscle, and the constant of integration h should remain finite for the velocity of light also,

But Einstein's postulate has compelled him to take $ds=0$ and therefore $h=\infty$ for light, with the result that for light the equation becomes

$$\frac{d^2u}{d\theta^2} + u = \frac{3\mu}{D^2} u^2$$

In order to calculate the spectral shift he has to make the impossible assumption of solar atoms being at rest, a fatal fallacy.

The New Theory gives the same equation both for matter and light and h remains finite. This difference furnishes the most crucial and decisive tests for the two rival theories to be verified by observation.

5. "The problem of two bodies on Einstein's theory remains an outstanding challenge to mathematicians - like the problem of three bodies on Newton's theory". (Eddington's Relativity; p. 95). In the new theory the problem causes no such insurmountable difficulty.

Let the bodies S and P, with masses M and m, have G as their common centre of gravity, then

(1) for the motion of P relative to S, the acceleration, is

$$-\frac{G(M+m)}{SP^2} - \frac{3GMh^2}{D^2} \cdot \frac{1}{SP^4} \dots \quad (10.21)$$

(2) For the actual motion in space, the acceleration is

$$-\frac{GM^3}{(M+m)^2} \frac{1}{GP^2} - \frac{3GM^3h^2}{D^2(M+m)^4} \frac{1}{GP^4} \dots \quad (10.22)$$

See Chapter VIII Sec. 2.

6. Three Bodies Problem.

Let S, E and M be the masses of the Sun, the Earth and the Moon, let R, r and ρ be the distances between them, and let H, h and η be the areal rates of the motion interse. Then by reducing the Earth to rest, we get the accelerations acting on the Moon *relative* to the Earth as

$$\frac{G(E+M)}{r^2} \left(1 + \frac{3h^2}{D^2 r^2} \right) \quad \text{along M E}$$

$$\frac{G S}{R^2} \left(1 + \frac{3H^2}{D^2 R^2} \right) \quad \text{along S E}$$

$$\text{and} \quad \frac{G S}{\rho^2} \left(1 + \frac{3\eta^2}{D^2 \rho^2} \right) \quad \text{along M S}$$

Take the Earth as origin of a set of rectangular coordinates, and let XYZ and x, y, z be the coordinates of the Sun and the Moon, the former being assumed to be known. Then the components of the acceleration acting on the Moon are

$$\begin{aligned}\frac{d^2x}{dt^2} &= -\frac{G(E+M)}{r^3} \left(1 + \frac{3h^2}{D^2r^2} \right) x - \frac{GS}{R^3} \left(1 + \frac{3H^2}{D^2R^2} \right) X \\ &\quad - \frac{GS}{\rho^3} \left(1 + \frac{3\eta^2}{D^2\rho^2} \right) (x - X) \quad \dots \quad (40.23)\end{aligned}$$

with similar expressions for $\frac{d^2y}{dt^2}$ and $\frac{d^2z}{dt^2}$ obtained by substituting y, Y and z, Z for x, X in the above. The three small extra terms in each equation cause a slight deviation from the classical theory.

It is easy to verify that as $xX + yY + zZ = R \cdot r \cos SEM$, the accelerations are given by the Potential function

$$\begin{aligned}V &= \frac{G(E+M)}{r} \left(1 + \frac{h^2}{D^2r^2} \right) + \frac{GS}{\rho} \left(1 + \frac{\eta^2}{D^2\rho^2} \right) \\ &\quad - \frac{GS}{R^2} \left(1 + \frac{3H^2}{D^2R^2} \right) r \cos SEM. \quad \dots \quad (40.24)\end{aligned}$$

This is the most general form for any three bodies.

SECTION III

The Equation of the Orbit

$$1. \text{ As } \frac{d^2u}{d\theta^2} + u = \frac{\mu}{h^2} + \frac{3\mu}{D^2} \cdot u^2.$$

Multiplying by $2\frac{du}{d\theta}$ and integrating we get

$$\left\{ \left(\frac{du}{d\theta} \right)^2 + u^2 \right\} = \frac{2\mu}{h^2} \cdot u + \frac{2\mu}{D^2} \cdot u^3 + K, \text{ where } K = \text{constant},$$

$$\text{Hence } \left(\frac{du}{d\theta} \right)^2 = \frac{2\mu}{D^2} \left[u^3 - \frac{D^2}{2\mu} \cdot u^2 + \frac{D^2}{h^2} \cdot u + \frac{D^2 K}{2\mu} \right] \\ = \frac{2\mu}{D^2} (u+a) [u^2 + Au + B] \dots \dots \quad (40.25)$$

$$\begin{aligned} \text{where } a+A &= -\frac{D^2}{2\mu} \\ Aa+B &= \frac{D^2}{h^2} \\ \text{and } a-B &= \frac{D^2 K}{2\mu} \end{aligned}$$

We know that there is always a factor $(u \pm a)$ if $f(\pm a) = 0$.

$$\text{Now put } u+a = z^2 \text{ and } \therefore \frac{du}{d\theta} = 2z \frac{dz}{d\theta}$$

$$\text{Hence } 4z^2 \left(\frac{dz}{d\theta} \right)^2 = \frac{2\mu}{D^2} \cdot z^2 [(z^2 - a)^2 + A(z^2 - a) + B]$$

$$\therefore \left(\frac{dz}{d\theta} \right)^2 = \frac{\mu}{2D^2} \left[z^4 + (A - 2a)z^2 + (a^2 - aA + B) \right]$$

$$\text{or } \theta = C \pm \frac{D\sqrt{2}}{\sqrt{\mu}} \cdot \int \frac{dz}{\sqrt{z^4 + (A - 2a)z^2 + (a^2 - aA + B)}}$$

This is reduceable into elliptic integrals. (40.26)

$$\text{Let } Z = z^4 + (A - 2a)z^2 + (a^2 - aA + B) = (z - \alpha)(z + \alpha)(z - \beta)(z + \beta)$$

$$\text{where } \pm \alpha, \pm \beta \text{ stand for } \pm \sqrt{\frac{-(A - 2a) \pm \sqrt{(A - 2a)^2 - 4(a^2 - aA + B)}}{2}}$$

then the general solution of the standard elliptic integral in Weierstrass's canonical form is

$$\theta = C \pm \frac{D\sqrt{2}}{\sqrt{\mu}} \cdot \frac{1}{2} \wp^{-1} \left(-\frac{H}{Z}; g_2, g_3 \right) \dots \dots \quad (40.27)$$

where \wp is Weierstrass's function and H denotes the Hessian of the

$$\text{quartic } Z \text{ i.e. } H = \frac{A - 2a}{6} \cdot z^4 + \left\{ (a^2 - aA + B) - \frac{(A - 2a)^2}{12} \right\} z^2 \\ + \frac{1}{6} (A - 2a) (a^2 - aA + B)$$

Also $g_2 = (a^2 - aA + B) + \frac{1}{12} (A - 2a)^2$

$$\text{and } g_3 = \frac{1}{6} (A - 2a) (a^2 - aA + B) - \frac{1}{2} \frac{1}{16} (A - 2a)^3.$$

[See Greenhill's Elliptic Functions Art. 75]

2. For a slightly different method of approach see Ch. I Sec. IX pp. 13-14, whence by putting $\kappa = 0$, we get

$$u = \frac{\mu}{h^2} + \frac{D^2}{6\mu} + \mathfrak{F} \left\{ \frac{1}{D} \sqrt{\frac{\mu}{2}} (\beta - \theta) \right\} \text{ neglecting smaller terms,}$$

β being a constant.

$$\text{where } \mathfrak{F}(z) = \frac{1}{z^2} + \sum_{m,n} \left\{ \frac{1}{(z - 2mw_1 - 2nw_2)^2} - \frac{1}{(2mw_1 + 2nw_2)^2} \right\}$$

The solution can then be expressed in series by successive approximations.

SECTION IV

Applications of the Law

Take the law of gravitation in the form $-\frac{\mu}{r^2} - \frac{3\mu h^2}{D^2} \cdot \frac{1}{r^4}$

(1) As the force is central, it causes no permanent perturbation in the major axis or the eccentricity. From Ch. I

$$\Delta a = 0 \quad \dots \quad (12.1)$$

$$\Delta e = 0 \quad \dots \quad (12.8)$$

(2) The advance of the perihelion is

$$\Delta \vartheta = \frac{6\pi\mu^2}{D^2 h^2}, \quad \text{exactly the same as Einstein's value.} \quad \dots \quad (12.12)$$

(3) (i) The deflection of the light from stars past the Sun lies

$$(a) \text{ between the minimum } \frac{16\mu}{3c^2 R}$$

$$\text{i.e. } 4/3 \text{ times Einstein's value.} \quad \dots \quad (14.6)$$

and (b) the maximum $\frac{6\mu}{c^2 R}$.

i.e. 3/2 times Einstein's value.

(Pr. Ac. Sc. 5, 159).

This tallies with Freundlich's value of $2''.23 \pm 10$ as a mean of values ranging from $1''.97$ to $2''.87$.

As the deviation from the straight path is small, the real value is nearer the maximum than the minimum.

(ii) An alternative proof for the maximum is given below.

Let δl be a small line element of light PP' and QQ' be its displaced position after time dt , let $PQ = dn$, $d\epsilon$ = angle between QQ' and PP', ψ = angle between the radius vector and the perpendicular distance R from the Sun on an asymptote, and c the velocity at P.

$$\text{Then } Q'P' - QP = \frac{dc}{dl} \cdot \delta l \cdot dt \text{ and also } = \delta l \cdot d\epsilon$$

$\frac{cd\epsilon}{dl}$ is the component of the acceleration along PP' = F

$$dn = cd़t$$

$$\text{Also } rd\psi = dn \cdot \cos \psi$$

$$\text{and } r \cos \psi = R$$

From these relations we get $d\epsilon = \frac{1}{c^2 R} (F \cdot r^3) d\psi$.

$$\epsilon = \frac{1}{c^2 R} \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} \left[-\frac{\mu}{r^3} - \frac{3\mu h^2}{c^2} \cdot \frac{1}{r^4} \right] r^2 \cos \psi d\psi$$

$$= -\frac{\mu}{c^2 R} \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} \left[\cos \psi + 3 \cos^3 \psi \right] d\psi, \text{ at the most}$$

as h is not less than $c \cdot R$, and the value of c

alters very little.

$$= -\frac{6\mu}{Rc^3} \dots \dots \dots \quad (40.28)$$

three times the Newtonian value. i.e. $2''61$.

These limits tally with Kluber's mean value $2''40$. (Zeitschrift Fur Astrophysik, Vol. 2, p. 319 of 1931.)

(4) The spectral shift of light from the centre of the Sun shown in Ch. XIV Sec. 5 § 6 is given by

$$\frac{\lambda_s}{\lambda_e} = \frac{V_s}{V_e} = \frac{1 + \frac{G}{c^2} \left(\frac{M}{a} + \frac{m}{d-a} \right)}{1 + \frac{G}{c^2} \left(\frac{M}{d-b} + \frac{m}{b} \right)} = 1 + \frac{GM}{c^2 a}, \text{nearly.....} \quad (40.29)$$

where M, m and a, b are the masses and radii of the Sun and the Earth, and d the distance between them. Hence the spectral shift is $= \frac{\mu}{c^2 a}$ (15.3)
which is the same as Einstein's value.

(5) The spectral shift of light from the edge of the Sun neglecting the effect of the Earth which is too small, is double of Einstein's value. (Pr. Nat. Ac. Sc. India, 1936. Vol. 6. part II. p. 186.)

The proof is as follows:—

$$\begin{aligned} V_r^2 &= c^2 + 2 \int \left(-\frac{\mu}{r^2} - \frac{3\mu h^2}{c^2} \frac{1}{r^4} \right) dr \\ \therefore V_s^2 &= c^2 + \frac{2\mu}{a} + \frac{2\mu h^2}{c^2} \frac{1}{a^3} \\ &= c^2 + \frac{4\mu}{a}, \text{ as } h=ca, \text{ nearly.} \end{aligned}$$

and $V_e^2 = c^2$ nearly.

$$\text{Hence } \frac{\lambda_s}{\lambda_e} = \frac{V_s}{V_e} = 1 + \frac{2\mu}{c^2} \frac{1}{a} \dots \dots \dots \quad (40.30)$$

which gives double of Einstein's value.

This result tallies exactly with the recent discovery made by Evershed,

and fully explains the "Edge Effect".

(M.N. of the R.A.S. **96**, 152, Jan. 1936).

(6) The spectral shift of light from the edge of the Sun is expressed as the difference in the potentials at the surfaces of the Sun and the Earth due to both the bodies

$$= \frac{G}{c^2} \left[M \left(\frac{1}{r} + \frac{h^2}{c^2 r^3} \right) - m \left(\frac{1}{d-r} + \frac{h'^2}{c^2(d-r)^3} \right) \right] \frac{a}{d-a} \dots \dots \quad (40.31)$$

$$= \frac{2GM}{c^2 a}, \text{ nearly as } h = ca.$$

(7) Neglecting the effect of the earth, which is very small, the spectral shift of light from any point on the solar surface is

$$\frac{GM}{c^2 a} (1 + \sin^2 \alpha), \text{ as } h = a \cdot c \sin \alpha \dots \dots \quad (40.32)$$

where α is the angle between the line of sight and the radius of the Sun, varying from 0 to $\frac{\pi}{2}$.

It is well-known that the Edge Effect can not be due to Compton scattering. Nor can it possibly be due to a Doppler effect, because from symmetry the motion of solar atoms should on an average be radial, and so perpendicular to the line of sight. It is fully explained by the New Theory only, and by none else.

The values for the deflection of light and the spectral shift from the edge are the two unique PREDICTIONS of the new theory. The formula giving the gradual change from the centre to the edge in the spectral shift contains more predictions and can be easily tested,

APPENDIX TO CHAPTER VIII SECTION 5.

Still Further Corrections.

Even if the effects of aberration and Doppler principle as shown in Ch. VIII Sec. 5 be ignored, the motion of the solar system will introduce new forces in addition to the attraction $\frac{k}{r^2}$ which would exist if both the Sun and the planet be at rest. Let the Sun S be moving with a constant velocity w through space, $SP=r$, let (x, y, z) be the co-ordinates of P with respect to S, v the velocity of P's motion relative to S; θ the angle between v and w, and let w_r be the component of w in the direction of r, and D the velocity of gravitation. Then as shown by H. A. Lorentz (Koninklijke Akademie van Wetenschappen te Amsterdam, Vol. II pp. 570-1) the additional forces will be:—

$$(1) \text{ A force in the direction of } r = k \frac{w^2}{2D^2} \frac{1}{r^2} \dots \quad (41.1)$$

(2) A force whose components are

$$\frac{-\kappa}{2D^2} \frac{\partial}{\partial x} \left(\frac{W_r^2}{r} \right); \frac{-\kappa}{2D^2} \frac{\partial}{\partial y} \left(\frac{W_r^2}{r} \right); \frac{-\kappa}{2D^2} \frac{\partial}{\partial z} \left(\frac{W_r^2}{r} \right) \dots \quad (41.2)$$

$$(3) \text{ A force parallel to the velocity } w = -\frac{\kappa}{D^2} w \cdot \frac{1}{r^2} \frac{dr}{dt} \dots \quad (41.3)$$

$$\text{and (4) A force in the direction of } r = \frac{\kappa}{D^2} \frac{w}{r^3} v \cos\theta. \quad (41.4)$$

Using the formulae given by Tisserand in his Mecanique Celeste, Lorentz calculated the secular variations in the elements of a planetary orbit due to these additional forces.

Let a be the mean distance from the Sun, e the eccentricity, ϕ the inclination to the ecliptic, θ the longitude of the ascending node, ω the longitude of perihelion, x the mean anomaly at time $t=0$ in this sense that if n be the mean motion, as determined by a , the mean anomaly

at time t is given by $x' + \int_0^t ndt$. Also let λ, μ, ν be the respective

direction cosines of the velocity w with respect to the radius vector of the perihelion, a direction obtained by giving to that radius vector rotation of 90° in the direction of the planet's revolution, and the normal to the plane of the orbit drawn towards the side when the planet is seen to revolve in the same direction as the hands of a watch. na is the velocity in a circular orbit of radius a .

Then the variations during one revolution are :—

$$\Delta a = 0 \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad (41.5)$$

$$\Delta e = 2\pi\sqrt{1-e^2} \left\{ \lambda\mu \frac{w^2}{D^2} \frac{2-e^2-2\sqrt{1-e^2}}{e^2} - \lambda \frac{wna}{D^2} \cdot \frac{1-\sqrt{1-e^2}}{e^2} \right\} \quad \dots \quad \dots \quad (41.6)$$

$$\Delta\phi = \frac{2\pi}{\sqrt{1-e^2}} \cdot \nu \cdot \left[\left\{ 1 - \lambda \frac{w^2}{D^2} \cos(\omega-\theta) + \frac{w}{D} \left(\frac{ena}{D^2} - \mu \frac{w}{D} \right) \sin(\omega-\theta) \right\} \times \frac{1-\sqrt{1-e^2}}{e^2} + \mu \frac{w^2}{D^2} \sin(\omega-\theta) \right] \quad \dots \quad (41.7)$$

$$\Delta\theta = -\frac{2\pi}{\sqrt{1-e^2} \sin\phi} \cdot \nu \cdot \left[\left\{ \lambda \cdot \frac{w^2}{D^2} \sin(\omega-\theta) + \frac{w}{D} \left(\frac{ena}{D} - \mu \frac{w}{D} \right) \cos(\omega-\theta) \right\} \times \frac{1-\sqrt{1-e^2}}{e^2} + \mu \cdot \frac{w^2}{D^2} \cos(\omega-\theta) \right] \quad \dots \quad (41.8)$$

$$\begin{aligned} \Delta\omega &= \pi(\mu^2 - \lambda^2) \cdot \frac{w^2}{D^2} \frac{2-e^2-2\sqrt{1-e^2}}{e^4} + 2\pi\mu \cdot \frac{wna}{D^2} \cdot \frac{\sqrt{1-e^2}-1}{e^3} \\ &\quad - \frac{2\pi\tan\frac{\phi}{2}}{\sqrt{1-e^2}} \cdot \nu \cdot \left[\left\{ \lambda \cdot \frac{w^2}{D^2} \sin(\omega-\theta) + \frac{w}{D} \left(\frac{ena}{D} - \mu \frac{w}{D} \right) \cos(\omega-\theta) \right\} \frac{1-\sqrt{1-e^2}}{e^2} \right. \\ &\quad \left. + \mu \cdot \frac{w^2}{D^2} \cos(\omega-\theta) \right]. \end{aligned} \quad \dots \quad (41.9)$$

$$\begin{aligned} \Delta x^1 &= \pi(\lambda^2 - \mu^2) \cdot \frac{w^2}{D^2} \cdot \frac{(2+e^2)\sqrt{1-e^2}-2}{e^4} - 2\pi \frac{w^2}{D^2} - 2\pi\mu^2 \frac{w^2}{D^2} \\ &\quad - 2\pi\mu \cdot \frac{wna}{D^2} \cdot \frac{(1-e^2)-\sqrt{1-e^2}}{e^3}. \end{aligned} \quad \dots \quad (41.10)$$

[Ibid p. 572.]

NITROGEN FIXATION IN SOIL WITH CELLULOSIC SUBSTANCES,
COWDUNG AND FATS

PART I

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SUMMARY

The authors report a marked increase in the total nitrogen when filter paper, dry leaves, leaf juice, cowdung etc. are mixed with soil and exposed to sunlight or diffused light. When small quantities of molasses are added to the cellulosic materials, there is greater nitrogen fixation. In sunlight there is more nitrogen increase than in diffused light. The authors conclude that like soluble carbohydrates, cellulosic materials, cowdung etc. when added to tropical soil lead to fixation of atmospheric nitrogen and also conserve the soil nitrogen. Even cowdung which has been used as a manure for its nitrogen from time immemorial has been found to supply the nitrogen it originally contains but it can also add nitrogen to the soil from the nitrogen of the air by fixation. These substances also add humus and increase the water retention capacity of the soil and protect the soil nitrogen.

Nitrogen fixation also takes place when the sodium salts of organic acids are allowed to oxidize in air on soil surface. With sodium stearate, palmitate and oleate, there is more nitrogen fixation than with sodium citrate. It appears, therefore, that the greater the amount of energy liberated in the oxidation, the greater is the amount of nitrogen fixed.

In recent publications¹, it has been shown that glucose, cane-sugar, mannitol, glycerol, starch, and the carbohydrates present in molasses when mixed with soil and allowed to oxidize, cause nitrogen fixation. Both the ammoniacal and total nitrogen of the soil increase. With molasses when added to soil in heaps, the total nitrogen is readily doubled. Applying 3 tons of molasses (containing 60% carbohydrates), 112 lbs of nitrogen are added per acre of land in field trials. It is believed that symbiotic nitrogen fixation adds 50-100 lbs of nitrogen per acre under normal conditions in temperate countries. Hence carbohydrate manuring with molasses appears to be an excellent proposition for adding nitrogen to tropical soils,

The following results show that when cellulosic materials cowdung and sodium salts of organic acids are mixed with soil and exposed to sunlight daily for 6 hours in dishes or kept in diffused light nitrogen fixation takes place. Some field trials with cowdung are also recorded.

In most of the experiments in light, about 66% of the total carbon and in the dark about 50% of carbon was oxidized in four to five months.

The results recorded in the tables show that the cellulosic substances like filter paper, dry leaf etc, when mixed with soil and exposed to sunlight or kept in the dark causes a marked increase of total nitrogen. When mixed with small amounts of molasses, the cellulosic substances undergo oxidation more readily and cause greater fixation of atmospheric nitrogen. The nitrogen fixation in light is greater than in the dark. Even cowdung which has been used as a fertiliser for its nitrogen content from time immemorial has been found to fix nitrogen. It supplies the nitrogen which it originally contains but it can also add nitrogen to the soil from the nitrogen of the air by fixation. These results are most important, because they show that cellulosic materials, plant residues, leaves, fine wood, cowdung etc. not only increase the humus and water content of the soil, and improves the physical condition of the soil, but also add nitrogen to the tropical soil by fixation of atmospheric nitrogen. We have also observed that carbonaceous substances in general conserve the soil nitrogen by retarding the velocity of nitrification. Hence it is clear why the nitrogen content of plots in Rothamsted receiving farmyard manure since 1843 is 0.256 per cent as against 0.099 per cent with complete artificials and 0.095 per cent with no manure. The cellulosic materials, pentosans etc. present in farm yard manure protect the soil nitrogen and fix atmospheric nitrogen. Russell² has reported that the nitrogen content of land laid down to grass increases from 0.152% in 1856 to 0.338% in 1912. This is chiefly due to the fixation of nitrogen and its conservation by the presence of energy-rich cellulosic and other materials in the soils. According to Mutterlein³ an acre of soil in Germany receives yearly about 200 Kgs of cellulose in the form of manure. It appears that this large amount of cellulosic matter added to the soil may be partially utilised in nitrogen fixation even in temperate climates and can protect the nitrogen by retarding the velocity of nitrification. In tropical climates, however, due to the high temperature and great intensity of sunlight and the greater activity of the Azotobacter, the soluble carbohydrates and cellulosic substances are oxidised fairly rapidly through the agencies of microorganism, sunlight and catalysts at

NITROGEN FIXATION WITH FILTER PAPER, DRIED LEAVES PLANT JUICE ETC.

| Conditions. | Originally present on 16-4-36. | kept in Sunlight. | | | | | Table 1. | | | | | kept in Diffused light. | | | | |
|--------------------------------------|---|------------------------------|------------------------------|------------------------------|------------------------------|----------------------------|------------------------------|------------------------------|------------------------------|-----------------------------|-----------------------------|------------------------------|------------------------------|------------------------------|-----------------------------|-----------------------------|
| | | on 5-5-36; | on 8-7-36; | on 11-8-36; | on 15-9-36; | on 29-10-36; | on 5-5-36; | on 8-7-36; | on 11-8-36; | on 15-9-36; | on 15-9-36; or | on 5-5-36; | on 8-7-36; | on 11-8-36; | on 15-9-36; | on 15-9-36; or |
| 500 gms soil + 25 gms filter paper. | NH ₃ -N = 0.0015% NO ₃ -N = 0.0029 Total-N = 0.0626 | 0.0019 % 0.0034 0.0752 | 0.0028 % 0.0041 0.0886 | 0.0031 % 0.0026 0.0886 | 0.0025 % 0.0028 0.0888 | 0.002 % 0.0026 0.089 | 0.0019 % 0.0034 0.0752 | 0.0026 % 0.0041 0.0834 | 0.0024 % 0.0025 0.0844 | 0.002 % 0.0022 0.0857 | 0.002 % 0.0022 0.0857 | 0.0019 % 0.0034 0.0752 | 0.0028 % 0.0038 0.0934 | 0.0024 % 0.0038 0.0944 | 0.002 % 0.0022 0.0955 | 0.002 % 0.0022 0.0955 |
| Same as above + 5 gms molasses. | NH ₃ -N = 0.0015 NO ₃ -N = 0.0029 Total-N = 0.0626 | 0.0019 0.0034 0.075 | 0.0028 0.0036 0.100 | 0.0031 0.0028 0.1010 | 0.0025 0.0032 0.112 | 0.0023 0.0028 0.112 | 0.0019 0.0034 0.0752 | 0.0034 0.0038 0.0934 | 0.0038 0.0027 0.0944 | 0.0016 0.0021 0.0955 | 0.0016 0.0021 0.0955 | 0.0019 0.0046 0.1922 | 0.0046 0.0056 0.1985 | 0.0042 0.0052 0.1985 | 0.0042 0.0052 0.1985 | 0.0042 0.0052 0.1985 |
| 500 gms soil + 100 gms dried leaves. | NH ₃ -N = 0.0043 NO ₃ -N = 0.0040 Total-N = 0.1362 | 0.0043 0.0062 0.173 | 0.0048 0.0077 0.185 | 0.0058 0.0054 0.200 | 0.0046 0.004 0.020 | 0.0031 0.0038 0.200 | 0.004 0.0062 0.175 | 0.0044 0.0064 0.175 | 0.0046 0.0056 0.1922 | 0.0042 0.0056 0.1985 | 0.0042 0.0052 0.1985 | 0.0044 0.0064 0.175 | 0.0046 0.0056 0.2198 | 0.0042 0.0056 0.222 | 0.0042 0.0052 0.222 | 0.0042 0.0052 0.222 |
| Same as above + 5 gms molasses. | NH ₃ -N = 0.0043 NO ₃ -N = 0.0040 Total-N = 0.1362 | 0.007 0.0062 0.1738 | 0.0048 0.0076 0.200 | 0.0063 0.0070 0.234 | 0.0046 0.005 0.2385 | 0.0035 0.0046 0.2321 | 0.0057 0.0062 0.1752 | 0.0042 0.0057 0.185 | 0.0057 0.0062 0.2198 | 0.0042 0.0062 0.222 | 0.0042 0.0062 0.222 | 0.0044 0.0057 0.185 | 0.0048 0.0062 0.2198 | 0.0042 0.0062 0.222 | 0.0042 0.0062 0.222 | 0.0042 0.0062 0.222 |
| 500 gms soil + 100 gms plant juice. | NH ₃ -N = 0.0059 NO ₃ -N = 0.0099 Total-N = 0.1093 | 0.0058 0.0046 0.112 | 0.0046 0.0054 0.119 | 0.0031 0.0043 0.116 | 0.0016 0.004 0.100 | 0.0015 0.004 0.0875 | 0.0057 0.0046 0.112 | 0.0052 0.0043 0.112 | 0.0048 0.0044 0.114 | 0.0042 0.0044 0.115 | 0.0042 0.0044 0.115 | 0.0044 0.0046 0.112 | 0.0048 0.0044 0.142 | 0.0042 0.0044 0.115 | 0.0042 0.0044 0.115 | 0.0042 0.0044 0.115 |
| Same as above + 5 gms molasses. | NH ₃ -N = 0.0059 NO ₃ -N = 0.0099 Total-N = 0.1093 | 0.0067 0.0046 0.118 | 0.0041 0.0037 0.148 | 0.0028 0.004 0.152 | 0.0023 0.004 0.122 | 0.002 0.004 0.0998 | 0.0058 0.0046 0.112 | 0.0042 0.0037 0.138 | 0.0042 0.0042 0.142 | 0.0042 0.0042 0.115 | 0.0042 0.0042 0.115 | 0.0044 0.0037 0.112 | 0.0048 0.0044 0.142 | 0.0042 0.0044 0.115 | 0.0042 0.0044 0.115 | 0.0042 0.0044 0.115 |

ISHERS AND IN THE FIELD

kept in Diffused light.

| on. 4-11-36 | on. 18-8-36 | on. 19-9-36 | on. 4-11-36 |
|-------------|-------------|-------------|-------------|
| 0,0021% | 0,0026 % | 0,0020 % | 0,0018 % |
| 0,0028 | 0,0035 | 0,0022 | 0,0026 |
| 0,140 | 0,100 | 0,112 | 0,1324 |
| 1,802 | 2,112 | 1,972 | 1,884 |
| | | | |
| 0,0018 | 0,0026 | 0,0019 | 0,0017 |
| 0,0026 | 0,0043 | 0,0021 | 0,0025 |
| 0,1386 | 0,100 | 0,112 | 0,1348 |
| 1,9224 | 2,148 | 2,00 | 1,938 |
| | | | |
| 0,0010 | 0,0018 | 0,0016 | 0,0008 |
| 0,0019 | 0,0023 | 0,0018 | 0,0018 |
| 0,0881 | 0,0822 | 0,0881 | 0,0882 |
| 4,2864 | 4,582 | 4,388 | 4,302 |
| | | | |
| 0,0014 | 0,0018 | 0,0013 | 0,0008 |
| 0,0018 | 0,0022 | 0,0018 | 0,0019 |
| 0,0888 | 0,0875 | 0,0881 | 0,0882 |
| 4,2944 | 4,582 | 4,349 | 4,3128 |

NITROGEN FIXATION IN SOIL WITH CELLULOSE

293

200 gms soil + 12.2 gms Sodium citrate
200 gms soil + 10.8 gms Sodium stearate.

STARTED ON. 13-3-36.

| | | | | |
|----------------------------|---|---------|---------|---------|
| $\text{NH}_3 - \text{N}$ | = | 0·0018% | 0·0018% | 0·0018% |
| $\text{NO}_3^- - \text{N}$ | = | 0·0016 | 0·0016 | 0·0016 |
| Total - N | = | 0·0458 | 0·0458 | 0·0462 |
| Total - C | = | 2·424 | 4·384 | 3·887 |

ANALYSED ON 14-3-36.

| | | | | |
|----------------------------|---|--------|--------|--------|
| $\text{NH}_3 - \text{N}$ | = | 0·0014 | 0·0011 | 0·0019 |
| $\text{NO}_3^- - \text{N}$ | = | 0·0014 | 0·0019 | 0·0014 |
| Total - N | = | 0·050 | 0·0583 | 0·054 |
| Total - C | = | 1·91 | 2·323 | 2·212 |

ANALYSED ON 16-7-36.

| | | | | |
|----------------------------|---|--------|--------|--------|
| $\text{NH}_3 - \text{N}$ | = | 0·0010 | 0·0010 | 0·0014 |
| $\text{NO}_3^- - \text{N}$ | = | 0·0016 | 0·0020 | 0·0028 |
| Total - N | = | 0·0492 | 0·0592 | 0·0542 |
| Total - C | = | 1·344 | 1·544 | 1·488 |

ANALYSED ON 10-10-36.

| | | | | |
|----------------------------|---|--------|--------|--------|
| $\text{NH}_3 - \text{N}$ | = | 0·0010 | 0·0010 | 0·0014 |
| $\text{NO}_3^- - \text{N}$ | = | 0·0016 | 0·0020 | 0·0027 |
| Total - N | = | 0·0492 | 0·0592 | 0·0538 |
| Total - C | = | 1·344 | 1·544 | 1·488 |

(S) 1.872

500 grms soil + 5 grms CaCo_3 and

Original, soil (a) 50 gms linseed oil

(b) 50 gms mahua oil

(c) 50 gms mustard oil

| | | |
|--------------------------|---|---------|
| $\text{NH}_3 - \text{N}$ | = | 0·0014% |
| $\text{NO}_3 - \text{N}$ | = | 0·0024 |
| Total - N | = | 0·056 |
| Total - C | = | 0·6067 |
| | | 0·0012% |
| | | 0·0017 |
| | | 0·0583 |
| | | 6·2886 |

| |
|---------|
| 0·0014% |
| 0·0018 |
| 0·0511 |
| 615·9 |
| |
| 0·0012% |
| 0·0017 |
| 0·0636 |
| 6·947 |

ANALYSED ON 11-9-36

| | |
|--------|--------|
| 0·0014 | 0·0016 |
| 0·0018 | 0·0022 |
| 0·0583 | 0·0583 |
| 5·991 | 6·000 |
| 6·428 | |
| 0·667 | |
| 0·0018 | |
| 0·0014 | |

$$\begin{array}{l} \text{NH}_3^+ - \text{N} \\ \text{NO}_3^- - \text{N} \\ \text{Total} - \text{N} \\ \text{Total} - \text{C} \end{array}$$

ANALYSED ON 19-10-36.

| | |
|--------|--------|
| 0·0014 | 0·0016 |
| 0·0018 | 0·0022 |
| 0·0583 | 0·0583 |
| 5·922 | 6·000 |
| 6·411 | 6·583 |
| 0·0667 | 0·0667 |
| 0·0019 | 0·0019 |
| 0·0016 | 0·0016 |

NH₃-N
NO₃-N
Total-N
Total-C

the soil surface with the liberation of large amounts of energy necessary for nitrogen fixation. Hence manuring of tropical soils with molasses, leaves, fine wood, cellulosic materials and their mixtures etc. is a highly important practical proposition. We are of the opinion that the nitrogen in Indian soils would have been exhausted long ago, but for this type of nitrogen fixation in soils. The results recorded in table II show that nitrogen fixation also takes place when sodium salts of organic acids are allowed to oxidise in air on soil surface, and the greater the amount of energy liberated in the oxidation the greater is the amount of nitrogen fixed. Thus with sodium stearate, palmitate and oleate, there is more nitrogen fixation than with sodium citrate.

Reference

1. Dhar and Mukerji, Proc Acad. Sci., U. P., **4**, 175, (1934) **4**, 330 (1935), **5**, 61, (1935), and J. Indian. Chem. Soc. **12**, 67 756, 1935, **13**, 155, 1936. Dhar and Sesacharyulu, Proc. National. Acad. Sci, **6**, 99, 1936.
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3. C. Mutterlin, Inaug. Diss. Leipzig (1913).

ALKALI SOILS AND THEIR RECLAMATION, PART II.

BY

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Chemistry Department, Allahabad University.

Received September 16, 1936

SUMMARY

1. Pressmud, which is available in large quantities in sugar factories, containing calcium compounds, carbohydrates, and nitrogenous substances has been found to be an excellent reclaiming agent for alkaline soils, as the chief defects of alkali soils are remedied by the addition of pressmud. Mixtures of molasses and pressmud can also reclaim alkali soils.

2. Oil cakes containing nitrogen compounds, oils, cellulosic materials etc. also remedy the defects of alkali soils and can reclaim alkali soils.

3. Using one ton of molasses per acre, the Mysore Government obtained 1200-1800 lbs of rice grain per acre of alkali land, where the crop failed completely in previous years. Very bad *Usar* soils have also been reclaimed and excellent rice crop has been obtained at Soraon (near Allahabad), Government Farm, Una, Cawnpore, Shahjehanpur and Behar.

4. Washing away of a normal soil by rain water or even good irrigation water removes more calcium than sodium and hence this leads to the formation of alkali soils from normal ones.

In a recent communication¹ it has been shown that when molasses is added to alkaline soils, the alkalinity is destroyed and the soil assumes the characteristics of normal ones. Further work in the reclamation of alkali soil is in progress in these laboratories and in this communication our recent results are recorded.

(Vide Table I)

Reclamation of Alkali Soil by Pressmud

It appears that nearly 300,000-400,000 tons of pressmud are being turned out by the sugar factories in India. This substance containing calcium salts, carbohydrates, and nitrogenous compounds are practically wasted. The following results (Vide Table II) show that when bad alkali soils, ($pH=10.8$) are mixed with pressmud, the pH becomes much

less and the alkali soils completely coagulate, showing increased permeability and flocculation of the particles. The calcium salts present in the pressmud convert the sodium soil into a calcium one. It appears, therefore, that the pressmud also is an excellent reclaiming agent for alkali soils. As pressmud is a solid substance and easy to transport, it should be largely utilised in reclaiming alkali soils.

Reclamation of Alkali Soils by Oil Cakes

Oil cakes containing about 4.7-7% nitrogen, oils, and cellulosic materials, have been found to neutralise the alkalinity of bad Usar soils. Hence oil cakes should be suitable reclaiming agents. It has been emphasised, that the chief defects of the alkali soils are high alkalinity, deficiency of nitrogen, organic matter, calcium, low permeability etc. Also most alkali soils lack bacterial activity. In most Indian alkali soils, the calcium content is not much less than that present in normal soils. The addition of oil cakes (Linseed, Mustard and Neem) has been found to remove the chief defects of an alkali soil and these are being utilised in reclaiming bad alkali soils.

Pot experiments with pressmud and oil cakes (Containing 1-2 parts of reclaiming agent in 100 parts of alkali soil of pH 10.8) as reclaiming agents show that rice plants can grow well in very bad Usar soils when mixed with pressmud or oil cakes and watered.

Field Trials

Last year, the Agriculture Department of Mysore Government applied to several fields 1 ton of molasses per acre of alkali land three weeks before the transplantation of rice. 1200-1800 lbs of rice grains per acre of alkali soil were obtained in the molassed fields where the crop completely failed in previous years. The normal production of rice in India is 1295 lbs per acre. As this Government is highly satisfied with these results they have extended their trial to 100 acres of alkali soil.

In the United Provinces molasses has been utilised in reclaiming alkali land at Soraon near Allahabad, Government Farm, Unao, Shahjehanpur and Cawnpore, and in all these places, excellent rice crop has been obtained in bad alkaline fields, where no vegetation ever grew. Using 3-10 tons of molasses per acre of land good results have been obtained.

even on bad *Usar* land. The amount of molasses to be added depends on the nature of the *Usar* soil.

Recently Mr. H. N. Batham working at Cawnpore and Dr. Mirehandani working at Sabour, Behar have confirmed our results and show that molasses is an excellent reclaiming agent even for bad alkali soils.

Mixtures of molasses with pressmud in different proportions have been found to be very effective in reclaiming bad *Usar* soils.

Using 10 tons of molasses per acre of very bad *Usar* soil ($\text{pH}=10.8$) at Soraon (Allahabad), 600 lbs of rice grains were obtained. The land had been entirely barren before the addition of molasses.

How a Normal Soil Can Become Alkaline?

1. It is well known that when a plant is burnt in air, alkali carbonates are left as residue. On the soil surface, similar oxidations take place at a small velocity. The carbonaceous and nitrogenous substances of the plant are steadily oxidized leaving only alkaline mineral residues. Hence the plants and their residues present in the soil can add alkali to the normal soil. It is well known that green manuring increases the alkalinity of a soil. Hence normal soils in tropical countries may become alkaline due to the oxidation and loss of the carbonaceous and nitrogenous portions of the organic substances. It is of interest to note here that the pH of soils collected from different countries are as follows:—

| Country | pH. |
|-------------|----------|
| Scotland | 5-6.4. |
| Finland | 5-6.4. |
| Japan | 4.5-6.9. |
| Denmark | 6-6.9. |
| Sweden | 6-7.4. |
| Java | 6.5-7.9. |
| Egypt | 7-9 |
| North India | 7-10.8. |

2. Experimental results obtained in different countries show that the exchangeable calcium varies from 63-92% of the total calcium of the normal soil. At Allahabad this percentage is 76. On the other hand, the exchangeable sodium or potassium does not exceed 11% of the total,

Hence when a normal soil is washed even with distilled water, more calcium is likely to be washed away than sodium or potassium. A sample of normal soil containing 1.21% CaO and 1.115% Na₂O, was washed with distilled water and the filtrate contained 0.025% CaO and 0.0115% Na₂O. Hence washing removes more calcium than sodium from a soil. It is well known that a normal soil is usually a calcium one and an alkaline soil is sodium soil. In other words, when the exchangeable calcium of a normal soil is washed away to a greater extent, the calcium soil will gradually pass into a sodium soil, which when hydrolysed produces sodium hydroxide. The carbonic acid of the air by interaction with sodium hydroxide forms sodium carbonate and bicarbonate. If the rain water or irrigation water washes away a normal soil year after year and the washed water is not retained by the soil, there is always the possibility of the formation of alkali soil from normal ones. According to this view point, for the conversion of normal soils to alkaline ones the soils need not be treated with sea water or saline water, but even repeated washing byin or good irrigation water may cause alkalinity of a normal soil. Therse considerations are in general agreement with the actual occurrence of *Usar* (alkaline) soils in different parts of the United Provinces and Madras Presidency.

Alkaline soil from Handia Tahsil, Allahabad, was treated with Press mud containing 44.8% carbon and 0.583% nitrogen on the 22nd Jan. 1936, and analysed on the 18th July 1936.

| | Condition | pH. | NH ₃ -N | NO ₃ -N. | Total-N. | Total-C. |
|----------------------------|---|-------|--------------------|---------------------|----------|----------|
| | Original. | 10.8. | 0.00108% | 0.00186% | 0.0256% | 0.2678% |
| Kept in the sunlight | 10 gms pressmud per kilogram of the soil. | 10.0. | 0.0008 | 0.0012 | 0.0274 | 0.3722 |
| | 20 gms. , , | 9.5 | 0.0008 | 0.0016 | 0.0297 | 0.3944 |
| | 50 gms. , , | 8.5 | 0.0030 | 0.0021 | 0.0467 | 0.5187 |
| | 100 gms. , , | 8.2 | 0.0032 | 0.0026 | 0.0631 | 0.7254 |
| | 200 gms. , , | 8.0 | 0.0058 | 0.0034 | 0.167 | 1.825 |
| Kept in the shade | 10 gms. , , | 10.5 | 0.00095 | 0.0011 | 0.091 | 0.412 |
| | 20 gms. , , | 10.5 | 0.00092 | 0.0012 | 0.0204 | 0.452 |
| | 50 gms. , , | 10.0 | 0.0011 | 0.002 | 0.047 | 0.628 |
| | 100 gms. , , | 9.5 | 0.0012 | 0.0022 | 0.050 | 0.925 |
| | 200 gms. , , | 9.0 | 0.0019 | 0.0026 | 0.07 | 2.114 |

ALKALINE SOIL FROM SORAON NEAR ALLAHABAD STARTED ON 2-12-35
ANALYSED ON 8-7-36.

| Condition | pH. | NH ₃ -N. | NO ₃ -N. | Total-N. | Total-C. |
|----------------------------------|------|---------------------|---------------------|----------|----------|
| Original. | 10.8 | 0.0010% | 0.0018% | 0.0256% | 0.2678% |
| 4 gms molasses per kilogram soil | 9 | 0.0009 | 0.0028 | 0.0042 | 0.2733 |
| 8 gms , , | 9 | 0.0009 | 0.0029 | 0.0072 | 0.3028 |
| 16 gms , , | 8.8 | 0.0009 | 0.0039 | 0.0048 | 0.375 |
| 32 gms , , | 8.5 | 0.0009 | 0.0042 | 0.0411 | 0.4 |
| 64 gms , , | 8.5 | 0.0010 | 0.0045 | 0.0432 | 0.4 |
| 80 gms , , | 8.5 | 0.0010 | 0.0059 | 0.044 | 0.4912 |
| 40 gms gypsum | 8.2 | 0.0008 | 0.0018 | 0.0033 | 0.2622 |
| 2 gms sulphur | 7.2 | 0.0008 | 0.0018 | 0.0033 | 0.6221 |

ALKALINE SOIL FROM SORAON NEAR ALLAHABAD STARTED ON 27-7-36
ANALYSED ON 21-8-36.

| | | | | | |
|---|------|--------|--------|--------|--------|
| Original | 10.8 | 0.0007 | 0.0031 | 0.025 | 0.2782 |
| 4 gms molasses + 2 gms CaCO ₃ per kilogram soil. | 9.8 | 0.0004 | 0.003 | 0.028 | 0.2821 |
| 8 gms , + 2 gms CaCO ₃ | 9.5 | 0.0007 | 0.003 | 0.031 | 0.3025 |
| 16 gms , , , , | 9.0 | 0.0007 | 0.003 | 0.0317 | 0.3348 |
| 32 gms , , , | 8.2 | 0.001 | 0.0028 | 0.0388 | 0.5189 |
| 64 gms , , , | 7.0 | 0.001 | 0.0028 | 0.0437 | 0.7365 |
| 80 gms , , , | 7.0 | 0.0011 | 0.0026 | 0.0518 | 0.9728 |
| 40 gms gypsum , | 8.6 | 0.0004 | 0.003 | 0.0238 | 0.2748 |
| 2 gms sulphur , | 10. | 0.0004 | 0.004 | 0.0258 | 0.2748 |

ANALYSED ON 22-9-36.

| | | | | | |
|--------------------------------------|------|--------|--------|--------|--------|
| 4 gms molasses + 2 gms | | | | | |
| CaCO ₃ per kilogram soil. | 9.8 | 0.0006 | 0.003 | 0.028 | 0.2812 |
| 8 gms , , , | 9.32 | 0.0009 | 0.003 | 0.0312 | 0.2921 |
| 16 gms , , , | 8.5 | 0.0010 | 0.003 | 0.0324 | 0.3233 |
| 32 gms , , , | 8.0 | 0.0013 | 0.003 | 0.0392 | 0.4952 |
| 64 gms , , , | 7.0 | 0.0015 | 0.0028 | 0.0447 | 0.6944 |
| 80 gms , , , | 6.8 | 0.0018 | 0.0026 | 0.0532 | 0.8287 |
| 40 gms gypsum , , | 8.5 | 0.0004 | 0.003 | 0.0232 | 0.2744 |
| 2 gms sulphur , , | 1.0 | 0.0004 | 0.003 | 0.0244 | 0.2744 |

STARTED ON 26-8-36.

| Condition | pH. | NH ₃ - N. | NO ₃ - N. | Total-N. | Total-C |
|-----------|------|----------------------|----------------------|----------|----------|
| Original | 10.8 | 0.0017 % | 0.0018 % | 0.0256 % | 0.2678 % |

ANALYSED ON 11-9-36.

| | | | | | |
|------------------------------|-----|--------|--------|--------|--------|
| 50 gms molasses + 100 gms | | | | | |
| pressmud per kilogram soil. | 6.8 | 0.0014 | 0.0021 | 0.0636 | 1.774 |
| 50 gms molasses + 50 gms | | | | | |
| press mud per kilogram soil. | 7.0 | 0.002 | 0.0021 | 0.0538 | 1.0288 |
| 100 gms , + 50 gms , , | 6.8 | 0.0023 | 0.0021 | 0.070 | 1.6059 |
| 100 gms , + 100 gms , , | 6.8 | 0.0030 | 0.0021 | 0.078 | 1.9831 |
| 25 gms , + 25 gms , , | 7.2 | 0.0013 | 0.0021 | 0.0412 | 0.6517 |
| 200 gms , + 200 gms , , | 6.4 | 0.0046 | 0.0021 | 0.140 | 4.932 |
| 200 gms , + 100 gms , , | 6.8 | 0.004 | 0.0023 | 0.127 | 3.894 |

ANALYSED ON 7-11-36.

50 gms molasses + 100 gms

| | | | | | |
|----------------------------|-----|--------|--------|--------|--------|
| pressmud per kilogram soil | 6.6 | 0.0022 | 0.0024 | 0.0717 | 1.1684 |
|----------------------------|-----|--------|--------|--------|--------|

50 gms molasses 50 gms

| | | | | | |
|----------------------------|-----|--------|--------|--------|--------|
| pressmud per kilogram soil | 6.8 | 0.0037 | 0.0026 | 0.0588 | 0.5758 |
|----------------------------|-----|--------|--------|--------|--------|

| | | | | | |
|------------------------|-----|-------|--------|--------|--------|
| 100 gms , + 50 gms , , | 6.6 | 0.004 | 0.0027 | 0.0719 | 1.0127 |
|------------------------|-----|-------|--------|--------|--------|

| | | | | | |
|-------------------------|-----|-------|--------|--------|-------|
| 100 gms , + 100 gms , , | 6.6 | 0.006 | 0.0028 | 0.0934 | 1.377 |
|-------------------------|-----|-------|--------|--------|-------|

| | | | | | |
|-----------------------|-----|--------|--------|--------|--------|
| 25 gms , + 25 gms , , | 7.0 | 0.0028 | 0.0023 | 0.0485 | 0.5822 |
|-----------------------|-----|--------|--------|--------|--------|

| | | | | | |
|-------------------------|-----|--------|--------|------|-------|
| 200 gms , + 100 gms , , | 6.2 | 0.0064 | 0.0035 | 0.14 | 2.551 |
|-------------------------|-----|--------|--------|------|-------|

| | | | | | |
|-------------------------|-----|--------|-------|-------|-------|
| 200 gms , + 100 gms , , | 6.2 | 0.0049 | 0.005 | 0.132 | 1.506 |
|-------------------------|-----|--------|-------|-------|-------|

Reference :-

Proc. Nat. Acad. Sci. India, 6, 136, 1936;

CHEMICAL EXAMINATION OF THE BARK OF *TERMINALIA*
ARJUNA BEDD, PART II.

THE ISOLATION OF ARJUNETIN FROM THE ALCOHOL EXTRACT.

BY RADHA RAMAN AGARWAL AND SIKHIBHUSHAN DUTT

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Received September 28, 1936.

SUMMARY

From the alcoholic extract of the bark of *Terminalia Arjuna* Bedd, have been isolated an amorphous red colouring matter m. p. 132°; arjunetin $C_{11}H_{18}O_4$, H_2O , m. p. 215° and reducing sugars. Arjunetin has been shown to contain a lactone ring and no hydroxy group.

In a previous communication Agarwal and Dutt¹ in the course of their investigations on the chemical examination of the bark of *Terminalia arjuna* Bedd, (Syn. Arjun) isolated from the benzene extract an acidic principle $C_{26}H_{32}O_{11}$ m. p. 180-182° C called by them arjunin. In the present paper the systematic chemical analysis of the bark is given. The analysis has shown that the bark contains arjunin (0. 2%) arjunetin (0. 25%) an amorphous red colouring matter (1%) and sugars.

Arjunetin is a white crystalline substance having the molecular formula $C_{11}H_{18}O_4$, H_2O . Although containing no phenolic hydroxy group since it does not give any colour with ferric chloride nor forms any derivatives with acetic anhydride or benzoyl chloride, it dissolves in alcoholic potash with a beautiful yellow colour. It also does not react with phenyl hydrazine, hydroxylamine or semi-carbazide, nor does it reduce Fehling's solution, but Tollen's reagent is at once reduced by it. These behaviours together with the fact that arjunetin decolourised bromine water and potassium permanganate which are shared by some of the natural coumarins, point to the irresistible conclusion that it probably contains a lactone ring. However, the experimental evidence at our disposal being so meagre nothing at present could be said regarding its exact constitution, but since the percentage of hydrogen is very high and the substance burns with a smoky flame it is probable that it may be a derivative of hexa-hydro-benzene.

Arjunetin is easily saponified by refluxing with alcoholic potash and on acidification an isomeric lactone is obtained. Since it reduces Tollen's reagent at once it seems very likely that it belongs to the group of $\Delta\beta\gamma$ lactones studied

by Thiele At present there seems to be no chemical relation existing between arjunin and arjunetin.

Experimental.

6 Kilograms of the dried and powdered bark of *Terminalia arjuna* Bedd was exhaustively extracted with benzene in a big extraction flask of 5-litre capacity. The benzene extract was treated separately whereby 12.4 grams of arjunin was obtained (Agarwal and Dutt loc. cit). The benzene free bark was then dried completely in order to free it from the last traces of the solvent and repeatedly extracted with boiling 95% ethyl alcohol. The alcoholic extract was of a deep red colour and on complete removal of the solvent gave a considerable amount of shining red brittle amorphous mass (150 gms.) It was then repeatedly extracted with benzene which removed a further quantity of arjunin (1.1 grams). After benzene extraction it was extracted with ethyl acetate and chloroform but no chemically definite product could be isolated from them.

Isolation of a Colouring matter.

The whole extract after the complete removal of the solvent was then dissolved in 1.5 litres of boiling ethyl alcohol. At this stage a certain amount of red soft crystalline matter remained undissolved which was filtered. The alcoholic solution was afterwards treated with an alcoholic solution of lead acetate whereby a flocculant dirty yellowish white precipitate of the lead salt was formed. It was filtered over a pump and washed thoroughly with alcohol. The lead salt was then suspended in ethyl alcohol and decomposed by passing a purified current of sulphuretted hydrogen in the usual manner. On concentration a syrupy dark red coloured mass was obtained which was further concentrated in vacuum dessicator and finally dried over anhydrous calcium chloride. It was then obtained as a dark red coloured amorphous mass, which was washed repeatedly with carbon-di-sulphide and ether. The appearance of the mass greatly improved by these treatments. Attempts were made to crystallise it from various solvents but without any success. Hence the amorphous colouring matter was purified further by refluxing it thoroughly with chloroform which removed some waxy matter. It was then dissolved in alcohol and was precipitated by pouring this alcoholic solution in a litre of ether. The purified colouring matter thus obtained was of a brownish red colour melting at 132° C. It was soluble easily in ethyl acetate, glacial acetic acid, pyridine and insoluble in water, ether, chloroform, benzene, toluene, carbon-di-sulphide and petroleum ether. It did not reduce Fehling's solution

by Thiele At present there seems to be no chemical relation existing between arjunin and arjunetin.

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either before or after hydrolysis, gave no reduction with Tollen's reagent. It gave a green colour with ferric chloride and a whitish yellow precipitate with alcoholic lead acetate. (Found C, 65.25, 65.50 ; H, 4.25, 4.57%.)

Isolation of Arjunetin.

The filtrate obtained after the separation of the lead salt of the colouring matter as described above, was of a light bluish green colour. In order to remove the excess of lead acetate a purified current of hydrogen sulphide was passed through the solution, and the precipitated lead sulphide was filtered off. The filtrate then became very light yellow in colour having a green fluorescence. The solvent was removed by distillation whereby a syrupy liquid remained behind. On adding a large amount of distilled water a flocculant white crystalline substance separated out. This was filtered over a pump and washed thoroughly with distilled water. It formed pale yellow white micro-crystalline powder, melting at 204° C after previous shrinking at 182° C (Yield 10.24 grams). The mother liquor was then concentrated over a water bath to about 50 cc. when on cooling a large amount of white crystalline material was deposited in well defined small plates. It was filtered over a pump with very good suction and washed thoroughly with water. It formed white crystalline mass on drying over sulphuric acid. It melted at 214° C after previous softening at 209° C (Yield 4.4 grams). The previous stuff obtained by precipitation with water was dissolved in a large volume of water and on concentration white well-defined plates were obtained melting at 214° C after previous softening at 210° C, and remained undepressed on admixture with the later substance. Hence the two substances were mixed together, and recrystallised from acetone in feathery crystals. It could also be crystallised from ethyl acetate in small needles and from iso-propyl alcohol in clusters of needles. The melting point of the recrystallised substance was 215° after previous shrinking at 210° and did not rise on further crystallisation. It is proposed to call this substance arjunetin in order to distinguish it from arjunin isolated from the benzene extract of the bark.

Properties of Arjunetin.

Arjunetin is soluble very easily in acetone, glacial acetic acid, pyridine and methyl alcohol : soluble on warming in ethyl alcohol, amyl alcohol and ethyl acetate and very little soluble in carbon-bi-sulphide and water. It is insoluble in chloroform, benzene, petroleum ether, ether and carbon-tetra chloride. It gives no colour with alcoholic ferric chloride, no precipitate with alcoholic lead

acetate or silver nitrate. It does not give any effervescence or colour with sodium-bi-carbonate and no colour with sodium carbonate, however in alcoholic potassium hydroxide it dissolves readily giving a beautiful yellow colour, and is reprecipitated on acidification. It does not reduce Fehlings' Solution but Tollen's reagent is very readily reduced by it. With concentrated sulphuric acid it first gives an orange yellow colour which gradually changes to red and finally becomes blood red. On standing it gives a beautiful violet colour from which a violet coloured precipitate separates on dilution with water. With concentrated nitric acid it gives a reddish yellow colour and with concentrated hydrochloric acid a dull yellow colour, which becomes colourless on warming. [Found C, 56.82, 56.76, 56.60; H, 8.6, 8.55, 8.74; H_2O 7.2, 7.5; M. W. (ebullioscopic in acetone) 228, 222; (titration with alcoholic alkali) 226; $C_{11}H_{18}O_4$, H_2O requires C 56.9; H 8.6; H_2O 7.7% M. W. 232: Found in sample dried at 110° for 18 hours C 61.6, H 8.6; $C_{11}H_{18}O_4$ requires C 61.7, H 8.4%.]

Saponification of Arjunetin :—1 gram of arjunetin was dissolved in 25 c. c of N/1.76 alcoholic caustic potash, and the whole thing refluxed over a water bath for five hours. On cooling the excess of alkali was titrated back with N/1.79 HCl using phenolphthalein as indicator. The saponification product was next isolated as usual by adding more of acid whereby white flakes were obtained m. p. 152° C. On recrystallisation from ethyl alcohol from which it was obtained in well defined colourless nodules melting sharp at 165° . It does not give any colour with ferric chloride, no precipitate with silver nitrate or lead acetate. (Found C. 61.3; H 8.9; $C_{11}H_{18}O_4$ requires C 61.7; H 8.4%).

The mother liquor after the separation of arjunetin as described above was then further examined. It reduced Fehling's Solution very easily and contained a large amount of reducing sugars. In order to identify the sugar a portion was treated in acetic acid media with phenyl hydrazine, when on warming in a water bath an osazone was prepared m. p. 203° C, showing the presence of glucose in the plant.

One of the authors (RRA) is highly indebted to the 'Kanta Prasad Research Trust' of the Allahabad University for a research Scholarship which enabled him to take part in this investigation.

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CHEMICAL EXAMINATION OF THE FRUITS OF *PHYSALIS*

PERUVIANA OR CAPE GOOSE BERRY PART I

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Communicated by Dr. S. Dutt.

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SUMMARY

The juice of the ripe berries of *Physalis Peruviana* (N. O. Solanaceae) called Cape Gooseberry in English and Makoi in Hindustani, has been shown to contain large quantity of pectin, free glucose (3 to 4 %), total glucose after hydrolysis (13·2 to 17 %), citric acid, malic acid and a trace of tartaric acid but no oxalic, benzoic or salicylic acid could be detected. Citric acid has been found to be present to the extent of 2.6 per cent and was estimated according to the method of L. Gowing Scopes.

Physalis Peruviana (N. O. Solanaceae) called Cape-gooseberry in English and Makoi in Hindustani is cultivated in India and hardly differs from *Physalis Minima* Linn, except in its large size and more oblong berry. It affords an excellent fruit and is much cultivated in the country. The berries are globular with slight elongation, about $\frac{3}{4}$ " in length and breadth; and have numerous pale yellow soft seeds embedded in juicy pulp. The berries when ripe are of a fine bright yellow colour. As far as the author is aware the fruits have not been chemically examined and consequently the berries have been subjected to detailed chemical examination.

The present investigation has shown that the juice of ripe berries contains citric acid (2. 6%) besides malic and tartaric acid, the latter only in traces, but no oxalic, salicylic, or benzoic acid was present. The juice also contains a large quantity of pectin matter, free glucose (3 to 4%) and the total reducing sugar after hydrolysis with dilute mineral acids amounted to 13 to 17 per cent. reckoned as glucose.

Experimental

Examination of the Juice :

The fruits were skinned from the husk by hand and the berries thus obtained formed 92% by weight of the former. The ripe berries were then

crushed thoroughly in a big enamelled dish with a wooden block and the pulp along with the seeds separated from the juice by cloth filtration. The pulp admixed with the seeds was thoroughly macerated with water by means of the block so that the seeds become detached from the pulp. The seeds which were heavier compared with the pulp settled at the bottom so that the juice and the pulp could be decanted off readily. On filtering the juice containing the pulp through cloth clear filtrate was obtained. The pulp was macerated twice and washed with water when some more seeds were obtained. The seeds thus obtained were washed with water in order to free them from sugars, dried in the sun by spreading in thin layers in big enamelled dishes and frequently turning over and constituted 4.5 to 5.0 % of the weight of husk-free fresh ripe berries.

The fresh as well as dialysed juice was tested as usual for enzymes. Peroxidase, catalase, invertase and diastase were totally absent but pectinase was present in considerable amount. The extracted juice if kept in a dish along with some finely powdered CaCO_3 set to a stiff jelly in the course of a few hours, showing the presence of pectin matter. The extracted juice was heated to 70° for 15 minutes in order to coagulate the proteins and pectin matter as well as to sterilise it and then filtered through filter paper. The filtered juice was used for determination of the constants as given below:—

Table I.

| | |
|--|------------------|
| 1. Density of the juice at 22° | 1.0530g. per cc. |
| 2. Total solid matter in the juice | 14.409 %. |
| 3. Total ash (mainly potassium and sodium carbonate; phosphate, sulphate being in traces) | 0.974 %. |
| 4. Total acidity, determined by titration with NaOH and reckoned as anhydrous citric acid, $\text{C}_6\text{H}_8\text{O}_7$:— | 2.202 %. |
| " " Sample A | 2.283 %. |
| 5. Free glucose :— | 4.36 %. |
| " " Sample A | 3.24 %. |
| 6. Total invert sugar after hydrolysis with mineral acids :— | 16.97 %. |
| " " Sample B | 13.23 %. |

*Isolation of Mixed organic acids :—*Two litres of the coagulated and filtered juice were neutralised with caustic soda using litmus as indicator and the mixed organic acids precipitated by means of excess of lead acetate solution. The almost white lead salt of the mixed acids was filtered and washed with cold water at the filter pump with good suction so as to free it completely from sugars. It was suspended in water and decomposed by excess of sulphurated hydrogen, and the filtrate from the resulting lead sulphide was concentrated on the water bath to a small bulk and allowed to stand for several days when crystals of the mixed acids separated. The resulting concentrated solution was tested for the various organic acids as follows :—

1. Salicylic acid :—The neutralised solution gave no violet coloration with ferric chloride showing the absence of salicylic acid.
2. Tartaric acid :—(a) Addition of a drop of ferrous sulphate and excess of caustic soda solution to 1 cc. of the solution containing a little H_2O_2 gave a light violet coloration which was discharged by sulphurous acid, showing thereby the presence of tartaric acid in traces. (b) To the solution an equal volume of alcohol was added and then a few drops of potassium acetate solution when on standing especially on scratching the sides of the test tube a slight turbidity appeared due to the formation of potassium hydrogen tartrate. (c) Precipitation with calcium chloride under specified condition showed the presence of citric acid in large amount as well as of malic acid, but proved the absence of oxalic and tartaric acids.
3. Citric acid :—(a) Denige's Test¹ showed the presence of citric acid. (b) Cadmium chloride gave a gelatinous precipitate insoluble in boiling water confirming its presence. (c) Its presence was also confirmed by Stahre's reaction² which is not affected by the presence of other organic acids or of chlorides unless these are present in great excess.
4. Malic acid :—To the concentrated solution of the mixed acids ammonium chloride, excess of ammonia and calcium chloride were added, the mixture boiled and the precipitate filtered; the filtrate gave a precipitate on addition of twice its volume of alcohol showing the presence of malic acid.

*Estimation of citric acid :—*Citric acid was estimated in the juice according to the following method of Gowing Scopes³. The reagent used for estimation was prepared by dissolving 68 cc. of con. HNO_3 , 51 gm. of mercuric nitrate and 51 gm. of manganese nitrate in 100 cc. of distilled water and making up the solution to 200 cc. 25 cc. of the juice were made up to 250cc. and 20 cc. of this diluted juice were carefully neutralised with N/10 alkali using phenolph-

thalin as indicator, 30 cc. of the reagent were added and the whole was diluted to 600 cc. and the liquid refluxed for three hours and the mercurial precipitate collected on a carefully weighed Gooch crucible, washed with cold water, dried in the water-oven for two hours and weighed. The weight divided by six equalled citric acid.

Table II

| Vol. of diluted Juice | Wt. of the mercurial ppt. in grams. | Remarks | Per cent of Citric acid. |
|--------------------------|---|---------------------------|-----------------------------|
| 25cc. | .2028 | Some metallic Hg present | 1.35 |
| 20cc. | .3116 | Ppt free from metallic Hg | 2.59 |
| 20cc. | .3101 | " " | 2.59 |
| 10cc. | .1560 | " " | 2.60. |
| 10cc. | .1557 | " " | 2.59. |

Separation of the acids :—To the concentrated and neutralised solution of the mixed acids ammonium chloride, excess of ammonium hydroxide and calcium chloride were added and the mixture boiled for ten minutes to precipitate the calcium citrate completely and the resulting precipitate (A) filtered at the pump.

The clear filtrate gave white crystalline precipitate (B) of calcium malate on addition of two volumes of alcohol. The air dried precipitate thus obtained from a large quantity of concentrated juice was treated with the calculated amount of dilute sulphuric acid and the filtrate on concentration on water bath and on keeping for a few days was filled with prismatic crystals which were filtered and esterified with absolute ethyl alcohol in presence of a little concentrated sulphuric acid. The resulting ester was fractionated under reduced pressure and the fraction having the b. p. 128—129°/12mm. was collected and was identified as ethyl malate. A portion of the acid twice crystallised from alcohol and dried in vacuum over calcium chloride melted at 100° (Found C, 35.41 ; H, 4.68 ; C₄H₆O₅ requires C, 35.82 ; H, 4.47),

The precipitate (A) was also decomposed with dilute sulphuric acid as described above and the clear filtrate from the resulting calcium sulphate on concentration to a syrup under reduced pressure deposited crystals melting at 98°-99°. These responded to all the specific tests of citric acid and were identified as such.

The author wishes to convey his heartiest thanks to Dr. S. Dutt, D.Sc., P.R.S., for his kind interest in the work.

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APPARATUS FOR THE MEASUREMEMENT OF RESPIRATORY QUOTIENT IN PLANTS

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SUMMARY

A simple manometric apparatus for the measurement of the ratio CO_2/O_2 in plants is described. Two to three seeds, approximately equal in size, are placed in each of the two vessels of the apparatus. In one of these vessels is placed a small glass cube and a volume equivalent piece of damp potash is placed in the other. The reading of one manometric limb. (h_{O_2}) indicates the pressure changes due to the absorption of oxygen (CO_2 produced being absorbed by the alkali) whereas the other (h) gives the resultant of oxygen uptake and CO_2 output. The required ratio is calculated by the equation : $R.Q.=h-h_{\text{O}_2}/h_{\text{O}_2}$.

For the quantitative determination of CO_2 produced in respiration Blackman's continuous current method is at once convenient and accurate, although when oxygen absorption is also to be recorded Haldane's gas-analysis apparatus is usually employed. When only R. Q. is needed, and not the actual amounts of oxygen absorbed and CO_2 evolved, it is rather inconvenient to go through the tedious process of gas analysis. In the course of investigations on the chemistry of respiration in *Pisum sativum* a simple apparatus for the measurement of R. Q. was developed in this laboratory and is described in the present note.

The two side-limbs (A) and (B), and the central pipette (C) of the apparatus (Fig. 1) are constructed out of a glass tubing with an internal cross-sectional area not exceeding $\frac{1}{2}$ sq. mm. The central pipette (C) carries a circular mark (X), corresponding with 150 mm. marks on the two side-limbs, beyond which it is blown into a small bulb (D), and carries a tap (E) at its extremity. The side-limbs carry mm. scales, 0 to 300, etched on them. A screw-clamp arrangement with a rubber reservoir (R) is provided, the manometric liquid (Brodie solution) being adjusted by means of a screw (S). The vessels (P) and (Q) are of the type used by Haines (see Fraymouth³) in his modification of the micro-respirometer of Barcroft and Winterstein. Arising from the base of each vessel is a fine capillary tube which communicates with the outside air and may be closed by means of a tap (M). The three limbs (A), (B) and (C) are enclosed within a glass jacket (J) the water in which is kept stirred during experimentation. It is arranged that both the vessels shall

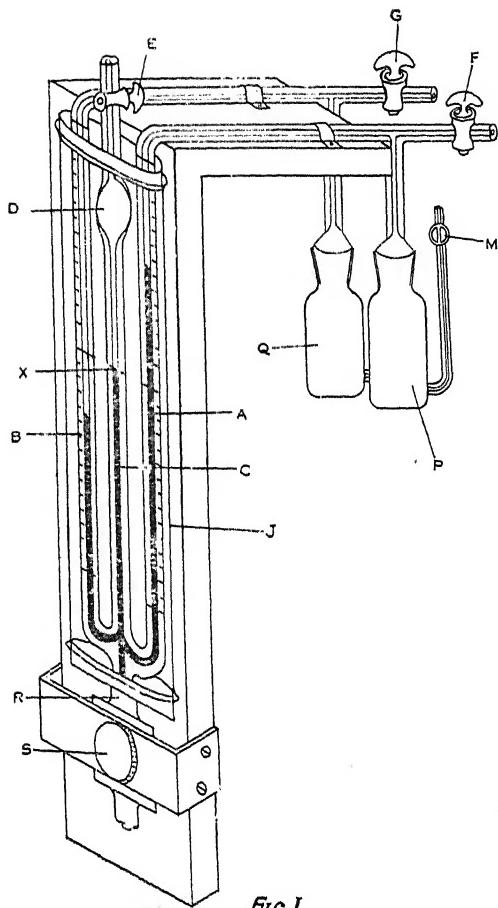


FIG. I.

have the same vessel-constant, methods of ensuring this have been described by Dickens and Greville¹ and Singh and Mathur⁴.

Lots of 2-3 seeds are placed in each vessel. It is very essential that the seeds should, so far as is possible in practice, be of the same size. In a series of well-controlled experiments the errors due to volume differences in various lots were found to be less than the error of scale reading (± 0.5 . mm.). As an extreme case the following example may be quoted: With two 22.5 ml. vessels a difference of 0.1 ml. in the gas spaces caused a difference of 0.6 mm. of Brodie solution when the reading of each manometric limb was of the order of 100 mm. As a difference of 0.1 ml. in the volumes of two lots of seeds (when only 2-3 seeds are placed in each vessel) is not considered likely to occur and the lengths of the Brodie solution involved are usually small, the slight volume difference introduces no

measurable error. It is not necessary that the two lots of seeds should be of equal weight, provided they are dried and weighed in the usual fashion at the end of the experiment. By dividing the reading of each manometric limb by the weight of seeds present in its vessel, the reading per mg. of dry weight is obtained and these should be substituted in the equation. Evidently the reading will be proportional to the weight of tissue, other things being equal.

The manipulation is easy. By means of the screw (S) the manometric liquid is adjusted to the mark (X) on the pipette (C) when it should also stand at the 150 mm. marks on both the side-limbs. During this adjustment all the three limbs (A), (B) and (C) are kept in communication with the air, the taps (E), (F) and (G) being subsequently closed. At the conclusion of the experiment the Brodie solution is again adjusted to the mark (X) on the pipette (C) and

the scale readings in the two graduated limbs are read. One vessel contains a small glass cube (with side = 5 mm.) and a volume equivalent piece of damp potash is placed in the other. One manometric limb will indicate the pressure changes due to absorption of oxygen (CO_2 produced being absorbed by the alkali) whereas the other limb gives the resultant of oxygen uptake and CO_2 production. Under such circumstances, R. Q. is easily calculated from the scale readings of the two graduated limbs. Let us assume that in a given time the lengths involved due to oxygen absorption and CO_2 evolution are h_{O_2} and h_{CO_2} respectively. From one limb h_{O_2} is directly read whereas the reading of the other limb, say h , gives the algebraic sum of h_{CO_2} and h_{O_2} :

$$h = h_{\text{CO}_2} + h_{\text{O}_2}$$

$$\text{or } h_{\text{CO}_2} = h - h_{\text{O}_2}$$

$$\text{whence } \text{R. Q.} = h - h_{\text{O}_2}/h_{\text{O}_2}$$

According to the usual convention in manometric methods (2) the readings in the above treatment have been considered positive or negative according as they indicate an evolution or an absorption of gas.

A few values of R. Q. obtained for *Pisum sativum* with the apparatus are presented in Table 1.

Table 1

| TIME | 25°C. | 30°C. | 35°C. |
|---------|-------|-------|-------|
| 7 A.M. | 2.84 | 2.13 | 1.92 |
| 10 A.M. | 2.03 | 2.09 | 1.96 |
| 1 P.M. | 1.72 | 1.73 | 1.48 |
| 4 P.M. | 1.78 | 1.47 | 1.31 |
| 7 P.M. | 1.27 | 1.26 | 1.05 |

Seeds were allowed to swell in distilled water for 10 hours after which the R. Q. measurements were made at 3 hour intervals. As germination proceeds the quotient gradually falls which shows an increased permeability of testa to oxygen. At the higher temperatures also the permeability of the testa to the entry of oxygen increases.

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SURFACE TENSION OF SOME COLLOIDAL SUBSTANCES

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In this paper surface tension of some naturally occurring lyophilic colloids and heavily hydrated inorganic colloids has been determined by a modified form of Traube's apparatus. The results prove that high hydration of colloid particles do not affect the surface tension of the dispersing medium appreciably and the dissolved substance present in true molecular state is responsible for the change in surface tension. The effects of electrolytes on the surface tension of these sols have been also casually studied.

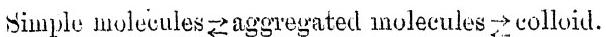
Lyophobic colloids have been differentiated from lyophilic ones in their property of depressing the surface tension of the dispersing medium. It is generally believed that the former affect the surface tension of the dispersing medium to a lesser degree than the latter. Dhar and coworkers¹ attribute this greater surface activity of the particles of the latter colloids to a large hydration of the colloid particles.

In order to throw further light on the phenomena, the static surface tension of naturally occurring lyophilic colloids such as gelatin, gumarabic, gum tragacanth, tannic acid and dextrin and also of highly hydrated and viscous colloids prepared in the laboratory such as vanadium pentoxide, zirconium and ferric hydroxides at different concentrations and temperatures both in the absence and the presence of electrolytes was determined.

The apparatus used in these experiments was a modified form of Traube's apparatus. The drops in this were allowed to fall at a pressure lower than the atmospheric pressure with a device which allowed a fairly longer time for the formation of the drops. Experiments were made at a minimum pressure which gave the maximum number of drops of the colloidal solution for a particular volume. Hence the arrangement may be said to give a fairly correct measure of static surface tension.

It has been shown by some workers² that gelatin produces maximum depression of surface tension at the iso-electric point. Similar results have been obtained by me. My experimental results show that when a sol of gelatin of P_H value 5.7 is made slightly acid, the surface tension is lowered to a minimum i.e. when the acid concentration is such that the P_H value of gelatin sol is not far removed from the iso-electric point, the lowering of surface tension is quite appreciable. In the case of tannic acid and gum arabic, surface tension is lowered continuously with increasing concentration of an acid. On the other hand, the surface tension increases continuously with the increasing concentration of an alkali in the case of gelatin and tannic acid.

Banerji and Ghosh³ have shown in a previous paper that the lyophilic colloids such as gelatin, agar agar etc, have some dissolved material in true molecular solution under the following equilibrium :—



The dissolved material if polaric in nature lowers the surface tension by being adsorbed on the surface. The greater the adsorption the greater is the lowering of the surface tension. The adsorption will be greater for the aggregated molecules than either the simple molecules or colloid particles.

It is seen from the experimental results with gelatin, tannic acid etc, that the greater the concentration of the sol, the higher is the lowering of surface tension. This is in accord with the views given above because at high concentrations greater amounts remain dissolved giving rise to greater number of simple molecules.

At the isolectric point the gelatin is at a maximum degree of aggregation and consequently show a maximum lowering of surface tension. The greater amount of an acid may dissolve more of colloidal material and consequently there will be a greater number of simple molecules with the result that the surface tension values will not be lowered to a greater extent. High concentrations of an acid depress the dissociation of the molecules that are formed and the depression of surface tension will again be large. The results obtained with 0.5%, 1% and 2% sols of gelatin support this conclusion. In the case of tannic acid and gum arabic the effect of acid is that the surface tension decreases continuously with increasing concentration of an acid. On the other hand, increasing concentrations of alkali decrease the surface tension continuously.

in the case of the latter two sols. It is probable that the solubilities of tannic acid and gum arabic being very little the colloid material gives greater number of aggregated molecules with the greater amount of acid whilst the alkali has a tendency to simplify the colloid particles.

It has been shown by Traube that the formula $\frac{\sigma_M - \sigma_L}{\sigma_M} = \alpha + \beta \cdot \log c$ (where

σ_M = surface tension of water, σ_L = surface tension of the solution and C = concentration of the solution and α and β are constants) agree very well in the case of concentrated solutions of sodium acetate and other salt solutions. It is seen that in the case of colloidal solutions of gelatin, tannic acid and other sols of various concentrations, this formula applies remarkably well. If

$\frac{\sigma_M - \sigma_L}{\sigma_M}$ is plotted on one axis and $\log c$ on the other, straight lines are

obtained. That the colloidal sols of gelatine, tannic acid, dextrin, gums arabic and taragacanth, and V_2O_5 contain at least a portion of them as dissolved materials is borne out by above considerations.

It has been suggested by some workers that in the case of lyophilic colloids the drop in surface tension values is associated with their high value of hydration. We know that in the case of gelatin maximum depression of surface tension occurs at the isolectric point where the viscosity and hence the degree of hydration is the minimum. Also sols like $Zr(OH)_4$ and V_2O_5 which are supposed to be highly hydrated have got very little effect in lowering the surface tension of water and behave like $Fe(OH)_3$ sol which is of hydrophobic character.

The effects of addition of salt solutions of different concentrations to the surface tension of sols like gelatin, tannic acid etc have casually been observed. The effect of normal solutions of monovalent salts in lowering the surface tension follows the order $Na > NH_4 > Li > K$ in the case of gelatin and the order $Li > Na > NH_4 > K$ in the case of tannic acid and gum arabic. Consequently no generalisation can be drawn of the effect of these salts on the surface tension of hydrophilic sols investigated here. It seems that the lowering of surface tension of water in the presence of a colloidal substance is not due to the high hydration of dispersed particles but originate from the presence of sufficient number of dissolved polaric and aggregated molecules.

In conclusion the author desires to express his indebtedness to Dr. S. Ghosh of the Allahabad University for his valuable suggestions in the progress of this work.

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FORMATION OF PERIODIC PRECIPITATE IN THE ABSENCE OF
A FOREIGN GEL

PART I FERRIC HYDROXIDE SOL

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This paper gives a study of periodic precipitation of ferric hydroxide sol, prepared by the acetate method, by coagulating with KCl and NaBrO₃. The lyophilic nature of the sol helps in the formation of periodic precipitates. The sol of concentration 0·71 gm. of Fe₂O₃ per litre and of purity 52.4. gave quite stable and good rings. The 'Peptisation Theory' of Chatterji and Dhar¹ for ring formation has been corroborated, and it has been shown that the adsorption of ferric hydroxide sol by its own precipitate is responsible for ring formation.

Liesegang² in 1896 observed for the first time that when saturated solution of silver nitrate is allowed to interact with potassium dichromate impregnated in gelatin spread over a glass plate, silver chromate precipitates in concentric rings. Since then many workers³ have reported the formation of Liesegang rings in gel medium of substances like gelatin, agar, starch, silicic acid etc. and also in the absence of another gel. Chatterji and Dhar⁴ have shown that all sparingly soluble substances under convenient conditions and in suitable gels would be capable of forming Liesegang rings.

In a communication⁵ from these laboratories to the 'Nature' it was reported that periodic precipitates can be obtained in the slow coagulation of the sols of ferric hydroxide, chromic hydroxide and stannic hydroxide by small quantities of univalent electrolytes like KCl, NaBrO₃ in the absence of a foreign gel. In this paper the conditions in which periodic precipitation of ferric hydroxide sol occurs, has been studied.

Ferric hydroxide sol was prepared by peptising freshly precipitated ferric hydroxide by minimum quantity of acetic acid which was then boiled off. The sol was further purified by hot dialysis. Different concentrations of the sol were taken in separate testubes and different amounts of mono and bivalent electrolytes were added to them and kept for slow coagulation. The conditions of the coagulums were observed after 24 hours, and these were repeated with sols of different purities. The following are the results:—

| | |
|--|--|
| Concentration of the sol A... | 39.2 gms. of Fe_2O_3 per litre |
| Amount of acetate... | 5.4 gms per litre |
| Purity*... | 2.72 |
| The sol and electrolyte were each made upto 10c.c. | |
| Total volume... | 20c.c. |

Table 1.

| Concentration of the sol | Amount of KCl | Condition of the coagulum. |
|--------------------------|-----------------|--|
| Sol A | 2c.c. to 10c.c. | All coagulated but no settling even after 5 days. The coagulum was jelly-like in character. |
| Sol A/2 | 4c.c. to 8c.c. | Same as before. After 48 hrs. with 8c.c. it showed many fine rings hardly to be distinguished from the whole volume of the coagulum. |

*The purity of the sol is expressed by the ratio of Fe_2O_3 to acetic acid obtained from the same volume of the sol, both the concentrations being expressed in grammoles per litre. (cf. ref. no.8)

| | | |
|----------|----------------|---|
| Sol A/4 | 5c.c. | The coagulum not settled. |
| | 6c.c. to 8c.c. | Same as before. After 48 hours the coagulum slightly settled and few faint rings appeared. |
| | 9c.c. | Many broad and dark coloured rings, separated by more light coloured space containing the coagulum, appeared. |
| Sol A/10 | 3c.c. to 6c.c. | The coagulum not settled. |
| | 7c.c. to 9c.c. | Slight settling. Many faint and fine rings appeared. |

(After 48 hours)

| | | |
|---|---------|--|
| | 3c.c. | No settling. |
| | 4c.c. | Many broad and dark rings in the upper half of the tube. |
| * | 5c.c. | Many broad and dark coloured rings in the upper half and fine rings in the lower half of the tube. |
| | 6c.c. | Same as before. |
| | 7c.c. | Same as before. |
| | 8c.c. | The entire rings of upper half broken |
| | & 9c.c. | due to settling. |

The number of rings with Sol A/10 were more than with higher concentrations of the sol.

TABLE 2.

| Concentration of the Sol | Amount of N/5 Na BrO ₃ . | Condition of the coagulum. |
|-----------------------------|--|---|
| Sol A/10 | 4c.c. and 5c.c. | Coagulation but no settling. |
| | 6c.c. | Many rings in spiral form. |
| (After 48 hours) | | |
| | 4c.c. | Few rings in the upper half. |
| | 5c.c. | Many broad and dark rings in the upper half and faint ones in lower half. |
| | 6c.c. | Same as before. |

Similar experiments were done with N/50 K₂ SO₄ and in every case coagulation took place instantaneously and the coagulums settled without any indication of ring formation.

The viscosity of the sol A/20 was 1.07 at 20°C (with respect to water).

In order to see the effect of the bore of the vessel in which the sol is coagulated on the process of periodic precipitation, the following experiments were performed :-

Tubings of 5 m.m. diameter were taken in which mixtures of Sol A/10 and N/3 KCl were sucked up and left to 24 hrs. for observation as done in the previous set of experiments. The tubing containing 9c.c. of N/3 KCl showed many plate like rings separated by clear spaces. It was observed that formation of rings is facilitated in experimenting with these tubings of small bore. First the nuclei started with coagulation and the precipitate adsorbed on the nuclei helped in more adsorption until the bands cleared themselves from the coagulum of their upper and lower strata, with the result, that the plates of the coagulum were formed and these were held in position due to the smallness of the bore of the tubing.

Effect of a surface on the ring formation.

Glass jets of about 0.5 m.m. diameter were held in the medium kept for ring formation. After sufficient time it was seen that there were many centres on the jets round which rings appeared and with time these spread radially reaching the sides of the test-tubes, thus giving us broad rings. This experiment proves that for ring formation a solid surface is necessary. On this surface the first nucleus of the precipitate makes its appearance, which in course of time grows bigger with more precipitate. The precipitate thus obtained adsorbs the sol present in the surroundings from the upper and lower strata. Thus the layers of the sol lying adjacent to the precipitate is very poor in ferric hydroxide content in the colloid condition which may get precipitated. In other words, around a layer of precipitate there exists no ferric hydroxide in the sol condition and consequently the layer appears as one separate ring.

The Sol was further purified by hot dialysis.

Concentration of the Sol A' ... 28.6 gms. of Fe_2O_3 per litre.

Amount of acetate ... 2.0 gms per litre

Purity ... 5.2

Various concentrations of the sol were tried for ring formation and the favourable concentration was found to be sol A'/10

Sol and electrolyte were each made up to 10 c.c.

Total volume... 20 c.c.

Table 3

| Concentration of the Sol. | Amount of KCl | Condition of the coagulum. |
|---------------------------|---|--|
| Sol A'/10 | 9,9.3,9.6,9.9 c.cs. 5,5.3,5.6 etc., to 8c.cs. | Rings developed but due to rapid settling all were broken. Coagulum partly settled and many broad and dark coloured rings appeared. |
| | | |

| Concentration of the Sol. | Amount of K Cl. | Condition of the coagulum |
|---------------------------|---|--|
| Sol A'/10 | 2, 2.3 etc to 4.7 c.c. (After 48 hrs). | Coagulum not settled. |
| | 2, 2.3 and 2.6 c.cs. | Coagulum not settled. Only few ring centres appeared. |
| | 2.9 to 4.7 c. c. | Broad and dark colour-ed rings. These rings were more stable than those with higher amount of the electrolyte. |

NaBrO_3 behaved like K Cl. No rings were obtained with K_2SO_4 as coagulant.

Viscosity of the Sol A'/20 at 20° was 1.08.

Viscosity of the Sol of concentration 1.96 gms of Fe_2O_3 per litre was 1.09.

The sol was further purified by hot dialysis.

Concentration of the sol A'' - 14.16 gm as of Fe_2O_3 per litre

Amount of acetate 0.1 gm per litre.

Purity 52.4

The favourable concentration in this case was found to be sol A''/10

Sol and electrolyte were each made up to 10 c. c.

Total Volume 20 c. c.

Table 4.

| Concentration of the Sol. | Amount of N/16 K Cl. | Condition of the coagulum. |
|---------------------------|----------------------|--|
| Sol A''/10 | 2 to 7 c.e. | Coagulation but no settling. |
| | 8 c.e. | Entire rings appeared but fewer in number. |

(After 48 hrs)

| | |
|-------------|--|
| 4 to 7 c.c. | Same as before. |
| 2 to 4 c.c. | No settling even after 24 hrs. or more. |

(Amount of N/200 K₂SO₄)

| | |
|---------------|--|
| 1, 1.5 c.c. | No Coagulation |
| 2 c.c. | Coagulum took much time to settle and after 6 hrs. broken rings appeared. |
| 2.5 to 4 c.c. | Immediate settling. |

NaBrO₃ behaved like KCl.

Viscosity of the Sol A"/20 at 20°C was 1.09.

Viscosity of the Sol of concentration 1.96 gms. of Fe₂O₃ per litre was 1.38.

Chatterji and Dhar⁶ have shown that freshly precipitated and well washed ferric hydroxide and silver chromate adsorbs their respective sols if they are well shaken and complete adsorption occurs when the amount of the precipitate is increased. They have extended their view in the mechanism of periodic precipitation in gel medium and Liesegang rightly calls it "Peptisations theorie von Dhar". It will be interesting to note here that Baly and Pepper could not get any adsorption of ferric hydroxide in the process of slow precipitation in a medium containing kieselguhr as adsorbent. In order to show that the adsorption of a colloidal substance by its precipitate is responsible for the ring formation during the process of slow coagulation as described in this paper, I performed the following experiments :—

Freshly precipitated ferric hydroxide was freed from the adsorbing electrolytes and was kept in suspension in distilled water. Definite volumes of this precipitate were taken in several 100 c.c. flasks with 5 c.c. of the original sol of known strength. Different amounts of electrolytes were added to these flasks, and total volumes made upto 100 c.c. The flasks were vigourously shaken and kept for 24 hours. The supernatant liquids, containing Fe₂O₃ in the sol condition, were gently pipetted out from the flasks and estimated. Knowing the amounts of Fe₂O₃ introduced

in the sol condition and those present in the sol condition after shaking, the percentage adsorption could be determined in each case. The following are the results:—

Purity of the Sol 0.97

Table 5.

| | | |
|---------------------------------------|---|--|
| Amount of precipitate taken each time | = | 0.2180 gms. of Fe_2O_3 |
| Amount of sol taken each time | = | 0.1872 gms. " " |

| Amount of N-K Cl | Amount of Fe_2O_3 in sol condition | % Adsorption. |
|---------------------|---|---------------|
| 0 c.c. | 0.229 gms. | —22.3 |
| 1 | 0.226. | —20.7 |
| 3 | 0.194. | —3.3 |
| 5 | 0.130. | 30.6 |
| 7 | 0.058, | 70.0 |

Table 6.

| | |
|---------------------------------------|--|
| Amount of precipitate taken each time | = 0.3276 gms. of Fe_2O_3 |
| Amount of sol taken each time | = 0.1872 gms. .. |

| Amt. of N-KCl | Amt. of Fe_2O_3 in sol condition | % Adsorption |
|------------------|---|--------------|
| 0 c.c. | 0.220 gms. | 17.5 |
| 1 | 0.202 | 7.9 |
| 3 | 0.106 | 43.4 |
| 5 | 0.048 | 74.4 |
| 7 | 0.015 | 92.0 |

In the absence of the precipitate, the same amount of the sol in 100c.c required 15 c.c. of the electrolyte to be partially coagulated,

Purity of the sol 5.2

Table 7.

Amount of precipitate taken each time = 0.228 gms. of Fe_2O_3
 Amount of sol taken each time = 0.1434 gms. , ,

| Amt. of N/2 KCl | Amt. of Fe_2O_3 in sol condition | % Adsorption |
|--------------------|---|--------------|
| 0 c.c. | 0.2 gms | -39.5 |
| 1 | 0.1512 | -5.4 |
| 2 | 0.045 | 69.1 |
| 3 | 0.0048 | 96.6 |

Table 8.

Amount of precipitate taken each time = 0.57 gms of Fe_2O_3
 Amount of sol taken each time = 0.1434 , , ,

| Amt. of N/2 KCl | Amt. of Fe_2O_3 in sol condition | % Adsorption |
|--------------------|---|--------------|
| 0 c.c. | 0.190 gms. | -32.5 |
| 1 | 0.126 | 12.1 |
| 2 | 0.038 | 73.5 |

In the absence of the precipitate, the same amount of the sol in 100 c.c. required 8.9 c.c. of the electrolyte to be partially coagulated.

Table 9.

Amount of the precipitate taken each time = 0.70 gms of Fe_2O_3
 Amount of the sol taken each time = 0.1434 gms " "

| Amt. of N/20 K_2SO_4 | Amt. of Fe_2O_3 in sol condition | % Adsorption |
|---|---|--------------|
| 0 c.c. | 0.175 gms. | -22.7 |
| 1 | 0.168 | -17.2 |
| 2 | 0.136 | 5.2 |
| 3 | 0.064 | 55.4 |

In the absence of the precipitate, the same amount of the sol in 100 c.c. required 2.0 c.c. of the electrolyte to be partially coagulated.

Purity of the sol 52.4

Table 10

| | |
|---|--------------------------------------|
| Amount of precipitate taken each time = | 0.22 gms. of Fe_2O_3 |
| Amount of sol taken each time = | 0.071 gms., , |

| Amt. of N/16 KCl | Amt. of Fe_2O_3 in sol condition | % Adsorption |
|---------------------|---|--------------|
| 0 c.c. | 0.08 gms. | -12.6 |
| 1 | 0.077 | -8.4 |
| 3 | 0.067 | 5.6 |
| 5 | 0.027 | 7.60 |
| 7 | 0.014 | 80.2 |

Table 11.

| |
|--|
| Amount of the precipitate taken each time = 0.44 gms. of Fe_2O_3 |
| Amount of sol taken each time = 0.071 gms., , |

| Amt. of N/16 KCl | Amt. of Fe_2O_3 in sol condition | % Adsorption |
|---------------------|---|--------------|
| 0 c.c. | 0.083 gms. | -17.0 |
| 1 | 0.080 | -8.4 |
| 3 | 0.027 | 76.0 |
| 5 | 0.0096 | 80.5 |

In the absence of the precipitate, the same amount of the sol in 100 c.c. required 10.2 c.c. of the electrolyte to be partially coagulated.

Table 12

| | |
|---------------------------------------|--|
| Amount of precipitate taken each time | = 0.22 gms. of Fe_2O_3 |
| Amount of sol taken each time | = 0.071 gms. ,, |

| Amt. of N/200 K_2SO_4 | Amt. of Fe_2O_3 in sol condition | % Adsorption |
|--|---|--------------|
| 0 c.c. | 0.077 gms. | -8.4 |
| 1 | 0.074 | -4.1 |
| 3 | 0.071 | --1.4 |
| 5 | 0.051 | 28.1 |
| 7 | 0.015 | 78.8 |
| 9 | 0.0016 | 98.0 |

In the absence of the precipitate, the same amount of the sol in 100 c.c. required 7.4 c.c. of the electrolyte to be partially coagulated. In this case adsorption occurs in the presence of K_2SO_4 . Indications of rings were obtained as well. In all cases it will be noted that there has been negative adsorption of the sol in the presence of smaller quantities of the electrolyte added. It is probable that the peptising electrolyte present in the sol peptises some of the precipitate of ferric hydroxide.

From the coagulation experiments it is seen that if the sol is coagulated rapidly by univalent precipitating ions no good rings are obtained, and no ring appears in the case of bivalent precipitating ions. It is well known that in the former case the coagulation is a slower process than the latter one, and consequently in these cases of bivalent precipitating ions, the precipitate can not coexist with the sol for sufficient length of time. Very concentrated sols are not suitable for the ring formation during the process of their coagulation, because the precipitate formed fills up the whole test tube. The coagulum should also be sufficiently hydrated for good ring formation so that the precipitate may not settle quickly. Hence the sols of higher purity yield better rings than impure ones.

The lyophilic character of the colloid particles plays an important part in ring formation. With most impure sol, where the coagulum obtained is not hydrated, no good rings are obtained. Casually it may be mentioned here, that no defined periodic precipitation could be observed with

ferric hydroxide sol prepared by Krecke's⁸ method, which is typically lyophobic one, whereas ferric hydroxide sol prepared by acetate method is a lyophilic colloid⁹ and very good rings are obtained with it. From the purity and viscosity data it may be concluded that the sol A''/₁₀ is more hydrated and the rings obtained with this sol are stable for about 48 hours and are held in position due to jelly-like character of the medium.

The author expresses his indebtedness to Prof. N. R. Dhar for his guidance in carrying out the work.

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THE NECESSARY AND SUFFICIENT CONDITION FOR THE
VALIDITY OF LEIBNIZ'S RULE FOR DIFFERENTIATION
UNDER THE SIGN OF INTEGRATION

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SUMMARY

In this paper the necessary and sufficient condition for the validity of Leibniz's rule—

$$\frac{d}{dy} \int_a^b f(x,y) dx = \int_a^b \left[\frac{d}{dy} f(x,y) \right] dx ,$$

is investigated; the notion of integration used is that of Riemann. The author, primarily has reduced the problem to that of finding out the necessary and sufficient condition for the equality of two repeated limits and then by applying a theorem on repeated limits, and simplifying, he obtained the result which is stated thus:—

"the necessary and sufficient condition in order that

$$\frac{d}{dy} \int_a^b f(x,y) dx = \int_a^b \left[\frac{d}{dy} f(x,y) \right] dx ,$$

(under certain restrictions imposed on the function $f(x,y)$) is that corresponding to an arbitrarily chosen positive number ϵ and to another arbitrarily chosen number η a number $h (< \eta)$ can be found and also a positive number α such that

$$m \left| \sum_{r=1}^{\frac{1}{m}} \left[\frac{1}{h} \left\{ f(a + \overline{b-a} rm, y+h) - f(a + \overline{b-a} rm, y) \right\} - \right. \right. \\ \left. \left. \left\{ \frac{d}{dy} f(a + \overline{b-a} rm, y) \right\} \right] \right|^{\alpha} < \epsilon$$

for every value of m in the interval $(0, \infty)$ which is reciprocal of a positive integer." In the last article the author has given an example to illustrate the result.

Introduction

The object of the present paper is to investigate the necessary and sufficient condition for the validity of Leibniz's rule for differentiation of a definite integral with respect to a parameter under certain restrictions imposed on the integrand. De la Vallee Poussin,¹ G. H. Hardy,² W. H. Young³ and others have given sufficient conditions, but the necessary and sufficient condition as far as I know has not yet been published.*

In art. (1) I give two lemmas, required in the investigation. In art (2) a theorem giving the result is enunciated and proved. In art (3) an example has been given to illustrate the theorem.

Art. (1) Lemmas :—

(a) If $f(n,h)$ be any function of the variable n (where n assumes only positive integral values) and $\lim_{n \rightarrow \infty} f(n,h)$ exists

(h being a constant) then

$$\frac{1}{h} \lim_{n \rightarrow \infty} f(n,h) = \lim_{n \rightarrow \infty} \frac{f(n,h)}{h}.$$

Proof:— Since $\lim_{n \rightarrow \infty} f(n,h)$ exists, call it $F(h)$ therefore if N_1, N_2, \dots be a

divergent sequence of integers, the sequence

$$f(N_1, h), f(N_2, h), \dots$$

converges to $F(h)$.

Let now e be an arbitrarily small positive number then an integer p can be found such that for all positive integral values of $q (> p)$

$$|f(N_q, h) - F(h)| < e \dots \dots \dots \quad (a)$$

Now when h is positive

$$\left| \frac{f(N_q, h)}{h} - \frac{F(h)}{h} \right| < \frac{e}{h}$$

which is also arbitrarily small.

This shows that the sequence

$$\frac{f(N_1, h)}{h}, \frac{f(N_2, h)}{h}, \dots$$

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converges to $\frac{F(h)}{h}$

$$\text{i.e. } \lim_{n \rightarrow \infty} \frac{f(N_n, h)}{h} = \frac{F(h)}{h} = \frac{1}{h} \lim_{n \rightarrow \infty} f(n, h)$$

Again if h is negative, divide both sides of the inequality (a) by $(-h)$ then

$$\left| \frac{f(N_q, h)}{-h} - \frac{F(h)}{-h} \right| < \frac{\epsilon}{-h}$$

which is positive and arbitrarily small.

But

$$\left| \frac{f(N_q, h)}{-h} - \frac{F(h)}{h} \right| = \left| \frac{f(N_q, h)}{h} - \frac{F(h)}{h} \right|$$

Therefore whether h be positive or negative

$$\frac{1}{h} \lim_{n \rightarrow \infty} f(n, h) = \lim_{n \rightarrow \infty} \frac{f(n, h)}{h}$$

(b) If $f(n)$ and $\phi(n)$ be any two functions of the variable n such that

$$f(n) = \phi(n)$$

for all finite values of n , and $\lim_{n \rightarrow \infty} f(n)$ exists and $= A$ then $\lim_{n \rightarrow \infty} \phi(n)$ exists

and $= A$,

the above lemma is obvious and does not require any proof.

Art. (2) Theorem:—

Let there be a function $f(x,y)$ of the variables x and y defined in the interval $a \leq x \leq b; c \leq y \leq d$; and satisfying the following conditions:—

1. It is bounded and integrable (R) with respect to x in the interval (a,b) .

2. The differential coefficient $\frac{d}{dy} f(x,y)$

exists for all values of x in (a,b) and every where in the domain (c, d) of y except at the end points where there are only one-sided derivatives.

3. $\frac{d}{dy} \int_a^b f(x,y) dx$ and $\int_a^b \left[\frac{d}{dy} f(x,y) \right] dx$

exist every where in the domain,

then the necessary and sufficient condition in order that

$$\frac{d}{dy} \int_a^b f(x, y) dx = \int_a^b \left[\frac{d}{dx} f(x, y) \right] dx.$$

is that corresponding to an arbitrarily chosen positive number ϵ and to another arbitrarily chosen number η a number $h (< \eta)$ can be found and also a positive number α such that

$$m \left| \sum_{r=1}^n \left[\frac{1}{h} \left\{ f(a + b - a/rm, y + h) - f(a + \overline{b-a}/rm, y) \right\} - \left\{ \frac{d}{dy} f(a + b - a/rm, y) \right\} \right] \right| < \epsilon$$

for every value of m in the interval $(0, \alpha)$ which is reciprocal of a positive integer.

Divide the interval (a, b) into n equal parts then since $\int_a^b f(x, y) dx$ exists as

an R-integral we have

$$\begin{aligned} \int_a^b f(x, y) dx &= \lim_{n \rightarrow \infty} \left[\sum_{r=1}^n \frac{b-a}{n} \left\{ f(a + \frac{b-a}{n} r, y) \right\} \right] \\ \therefore \frac{d}{dy} \int_a^b f(x, y) dx &= \\ \lim_{\epsilon \rightarrow 0} \lim_{n \rightarrow \infty} \left[\sum_{r=1}^n \frac{b-a}{n} \left\{ f(a + \frac{b-a}{n} r, y+h) - f(a + \frac{b-a}{n} r, y) \right\} \right] &- \lim_{n \rightarrow \infty} \left[\sum_{r=1}^n \frac{b-a}{n} \left\{ f(a + \frac{b-a}{n} r, y) \right\} \right] \\ &= \lim_{h \rightarrow 0} \frac{1}{h} \lim_{n \rightarrow \infty} \left[\sum_{r=1}^n \frac{b-a}{n} \left\{ f\left(a + \frac{b-a}{n} r, y+h\right) - f\left(a + \frac{b-a}{n} r, y\right) \right\} \right] \end{aligned}$$

$$\begin{aligned}
 &= \lim_{h \rightarrow 0} \lim_{n \rightarrow \infty} \left[\sum_{r=1}^n \frac{b-a}{nh} \left\{ f \left(a + \frac{\overline{b-a}}{n} r, y+h \right) \right. \right. \\
 &\quad \left. \left. - f \left(a + \frac{\overline{b-a}}{n} r, y \right) \right\} \right] \text{ by Lemma} \\
 &= \lim_{h \rightarrow 0} \lim_{m \rightarrow \infty} \left[\sum_{r=0}^m \frac{(b-a)m}{h} \left\{ f \left(a + \overline{b-a} rm, y+h \right) - f \left(a + \overline{b-a} rm, y \right) \right\} \right]
 \end{aligned}$$

where $m = \frac{1}{n}$ (m therefore assumes only those real values which are reciprocal to positive integers).

Again the expression

$$\begin{aligned}
 &\int_a^b \left[\frac{d}{dy} f(x, y) \right] dx = \int_a^b \left[\lim_{\eta \rightarrow 0} \frac{1}{\eta} \left\{ f(x, y+\eta) - f(x, y) \right\} \right] dx \\
 &= \lim_{n \rightarrow \infty} \left[\sum_{r=1}^n \frac{b-a}{n} \lim_{\eta \rightarrow 0} \frac{1}{\eta} \left\{ f \left(a + \frac{\overline{b-a}}{n} r, y+\eta \right) - f \left(a + \frac{\overline{b-a}}{n} r, y \right) \right\} \right] \\
 &\quad \text{but } \left[\sum_{r=1}^n \frac{b-a}{n} \lim_{\eta \rightarrow 0} \frac{1}{\eta} \left\{ f \left(a + \frac{\overline{b-a}}{n} r, y+\eta \right) - f \left(a + \frac{\overline{b-a}}{n} r, y \right) \right\} \right] \\
 &= \left[\sum_{r=1}^n \lim_{\eta \rightarrow 0} \frac{b-a}{n\eta} \left\{ f \left(a + \frac{\overline{b-a}}{n} r, y+\eta \right) - f \left(a + \frac{\overline{b-a}}{n} r, y \right) \right\} \right] \text{ by Lemma} \\
 &= \lim_{\eta \rightarrow 0} \left[\sum_{r=1}^n \frac{b-a}{n\eta} \left\{ f \left(a + \frac{\overline{b-a}}{n} r, y+\eta \right) - f \left(a + \frac{\overline{b-a}}{n} r, y \right) \right\} \right]
 \end{aligned}$$

for all finite values of n .

$$\therefore \lim_{n \rightarrow \infty} \left[\sum_{r=1}^n \frac{b-a}{n} \lim_{\eta \rightarrow 0} \frac{1}{\eta} \left\{ f \left(a + \frac{\overline{b-a}}{n} r, y+\eta \right) - f \left(a + \frac{\overline{b-a}}{n} r, y \right) \right\} \right]$$

$$\begin{aligned}
 &= \lim_{n \rightarrow \infty} \lim_{\eta \rightarrow 0} \left[\sum_{r=1}^n \frac{b-a}{n\eta} \left\{ f\left(a + \frac{b-a}{n} r, y + \eta\right) - f\left(\frac{b-a}{n} r, y\right) \right\} \right] \text{ by lemma (b § 1)} \\
 &\therefore \int_a^b \left[\frac{d}{dy} f(x, y) \right] dx = \lim_{n \rightarrow \infty} \lim_{\eta \rightarrow 0} \left[\sum_{r=1}^n \frac{b-a}{n\eta} \left\{ f\left(a + \frac{b-a}{n} r, y + \eta\right) - f\left(a + \frac{b-a}{n} r, y\right) \right\} \right] \\
 &= \lim_{m \rightarrow 0} \lim_{\eta \rightarrow 0} \left[\sum_{r=1}^{\frac{1}{m}} \frac{(b-a)m}{\eta} \left\{ f(a + \overline{b-a} rm, y + \eta) - f(a + \overline{b-a} rm, y) \right\} \right]
 \end{aligned}$$

where m is $\frac{1}{n}$ as before.

The problem now reduces itself to the finding out of the necessary and sufficient condition in order that

$$\begin{aligned}
 &\lim_{h \rightarrow 0} \lim_{m \rightarrow 0} \left[\sum_{r=1}^{\frac{1}{m}} \frac{(b-a)m}{h} \left\{ f(a + \overline{b-a} rm, y + h) - f(a + \overline{b-a} rm, y) \right\} \right] \\
 &= \lim_{m \rightarrow 0} \lim_{\eta \rightarrow 0} \left[\sum_{r=1}^{\frac{1}{m}} \frac{(b-a)m}{\eta} \left\{ f(a + \overline{b-a} rm, y + \eta) - f(a + \overline{b-a} rm, y) \right\} \right] \\
 &= \lim_{m \rightarrow 0} \lim_{h \rightarrow 0} \left[\sum_{r=1}^{\frac{1}{m}} \frac{(b-a)m}{h} \left\{ f(a + \overline{b-a} rm, y + h) - f(a + \overline{b-a} rm, y) \right\} \right]
 \end{aligned}$$

since it makes no difference if we write h for η , the function inside the square brackets on the left-hand side being the same function of h as the function on the right hand side inside the square brackets is of η .

Now a theorem⁴ on repeated limits given by Hobson is applied.

The function $f(x, y)$ already satisfies the first condition⁵ of the above theorem as shown.

below:—

$$\text{Since } \lim_{h \rightarrow 0} \left[\sum_{r=1}^{\frac{1}{m}} \frac{(b-a)m}{h} \left\{ f(a + \overline{b-a} rm, y+h) - f(a + \overline{b-a} rm, y) \right\} \right] \text{ exists}$$

therefore the upper and lower limits are identical and approach the same limits as $m \rightarrow 0$

Similarly since

$$\lim_{m \rightarrow 0} \left[\sum_{r=1}^{\frac{1}{m}} \frac{(b-a)m}{h} \left\{ f(a + \overline{b-a} rm, y+h) - f(a + \overline{b-a} rm, y) \right\} \right] \text{ exists}$$

the upper and lower limits are identical and approach the same limits as $h \rightarrow 0$

Now as far the second condition ⁶

$$\because \lim_{h \rightarrow 0} \left[\sum_{r=1}^{\frac{1}{m}} \frac{(b-a)m}{h} \left\{ f(a + \overline{b-a} rm, y+h) - f(a + \overline{b-a} rm, y) \right\} \right]$$

exists, therefore the latter part of it applies.

Noting that for Hobson's 'x' and 'y' I have 'm' and 'h' respectively in my function the condition is as follows:—

"Corresponding to any arbitrarily chosen positive number ϵ and to an arbitrarily chosen value η of h a value h ($< \eta$) of h can be found out, and also a positive number α such that the condition

$$\left| \sum_{r=1}^{\frac{1}{m}} \left[\frac{m(b-a)}{h_1} \left\{ f(a + \overline{b-a} rm, y+h_1) - f(a + \overline{b-a} rm, y) \right\} \right] - \lim_{h \rightarrow 0} \sum_{r=1}^{\frac{1}{m}} \frac{m(b-a)}{h} \left\{ f(a + \overline{b-a} rm, y+h) - f(a + \overline{b-a} rm, y) \right\} \right] < \epsilon$$

is satisfied for every value of m within the interval (α, ∞)

The above condition can be written as

$$m \left| \sum_{r=1}^{\frac{1}{m}} \left[\frac{1}{h_1} \left\{ f(a + b - a rm, y + h_1) - f(a + b - a rm, y) \right\} - \frac{d}{dy} f(a + b - a rm, y) \right] \right| <_{b-a} e' <_{e'} e$$

where $e' = \frac{e}{b-a}$ is also an arbitrarily small positive number.

Art 3. Example :—

$$\text{Let } f(x, y) = \begin{cases} -\frac{y}{x} \left(1 + \frac{y}{x}\right) & \text{when } x \neq 0 \\ 0 & \text{when } x = 0 \end{cases} \quad 0 \leq x \leq 1 - y_1 \leq y \leq y_2$$

Where y_1 and y_2 are positive constants.

The condition of the theorem of Art. 2 is not satisfied for the function $f(x, y)$ at $y=0$ as shown below :—

$$m \left| \sum_{r=1}^{\frac{1}{m}} \left[\frac{1}{h_1} \left\{ f(a + b - a rm, y + h_1) - f(a - b - a rm, y) \right\} - \frac{d}{dy} \right. \right. \\ \left. \left. \left\{ f(a + b - a rm, y) \right\} \right] \right| = \left| \sum_{r=1}^{\frac{1}{m}} \left[\frac{1}{h_1} \left\{ \frac{1 + \frac{h_1}{rm}}{\frac{h_1}{rm}} - 1 \right\} \right] \right| \text{at } y = 0 \quad \dots \quad (\text{A})$$

Let now $F(r)$ be a function of r such that

$$F(r) = \frac{1 + \frac{h_1}{rm}}{e^{h_1/rm}}, \quad \text{for all real values of } r \text{ in the interval} \\ 1 \leq r \leq \frac{1}{m}$$

then

$$\frac{d F(r)}{dr} = \frac{h_1^2}{r^3 m^2} \cdot \frac{1}{e^{h_1/rm}}$$

which is clearly a positive quantity.

This shows that the value of the function $1 + \frac{h_1}{rm}$
 $\frac{e^{h_1/rm}}{e^{h_1/(r+m)}}$

increases as r increases

$$\therefore \frac{1 + \frac{h_1}{(r+1)m}}{e^{h_1/(r+m)}} > \frac{1 + \frac{h_1}{rm}}{e^{h_1/rm}}$$

i.e. if the function $1 + \frac{h_1}{rm} / e^{h_1/rm}$ is defined only for integral values of r then

$$\frac{1 + \frac{h_1}{rm}}{e^{h_1/rm}} < \frac{1 + \frac{h_1}{(r+1)m}}{e^{h_1/(r+1)m}} \text{ for } r = 1, 2, 3, \dots, \left(\frac{1}{m} - 1\right)$$

also because $1 + \frac{h_1}{rm} / e^{h_1/rm}$ is always less than 1 for all values of r therefore

$$\left| \frac{1 + \frac{h_1}{rm}}{e^{h_1/rm}} - 1 \right| > \left| \frac{1 + \frac{h_1}{(r+1)m}}{e^{h_1/(r+1)m}} - 1 \right|$$

Therefore the last term namely the $\frac{1}{m}$ th term of the series (A) is the numerically least term.

$$\therefore \left| \sum_{r=1}^{\frac{1}{m}} \left[\frac{m}{h_1} \left\{ \frac{1 + \frac{h_1}{rm}}{e^{h_1/rm}} - 1 \right\} \right] \right| > \frac{1}{h_1} \left\{ \frac{1 + h_1}{e^{h_1}} - 1 \right\}$$

which is not arbitrarily small for a fixed h_1 .

$$\therefore \frac{d}{dy} \int_0^1 \left[e^{-x} \left\{ 1 + \frac{y}{x} \right\} \right] dx \quad \text{at } y=0$$

cannot be equal to

$$\int_0^1 \left[\frac{d}{dy} \left\{ e^{-x} \left(1 + \frac{y}{x} \right) \right\} \right] dx \quad \text{at } y=0.$$

As a matter of fact

$$\frac{d}{dy} \int_0^1 \left[e^{-\frac{y}{x}} \left\{ 1 + \frac{y}{x} \right\} \right] dx = 1 \quad \text{at } y=0.$$

and

$$\int_0^1 \left[\frac{d}{dy} \left\{ e^{-\frac{y}{x}} \left(1 + \frac{y}{x} \right) \right\} \right] dx = 0 \quad \text{at } y=0.$$

I take this opportunity to express my indebtedness to Dr. Lakshmi Narayan under whose guidance this investigation has been carried out.

References

- (1) Ann. de la Soc. Sc. de Bruxelles Vol. XVI (B) (1891-2).
- (2) Quarterly Journal of Math. Vol. XXXII (1901) p. 66.
- (3) Trans. Cambi. Phil. Soc. Vol. XXI. (1901) p. 397.
- (4) Hobson's "Theory of Functions etc." Vol. I p. 413
 (3rd Ed.) "The necessary and sufficient condition that....in the interval $(a, a+\alpha)$ ".
 The same theorem in a different form is given by Hobson in Proc. Lond. Math. Soc. (2) Vol. V 1907 p. 226.
- (5) Hobson's "Theory of Functions etc." Vol. I p. 413, Lines 9—11 (3rd Ed) viz
 "that $\overline{\lim}_{x \sim a} f(x,y)$ converge...for $x \sim a$ " 9—11
- (6) Hobson's "Theory of Functions etc." Vol. I p. 413 Lines 11—I9 (3rd Ed) viz
 "that corresponding.....within the interval $(a, a+\alpha)$."

*After this paper was sent to the press, I came across a paper "Sur La dérivation de L'intégrale par rapport au paramètre" by Miroslaw Krzyzanski published in "Comptes Rendus Des Séances De La Société Des sciences Et Des Letters De Varsovie" class III; XXVI Anncé 1933 ; Fascicule ; 7-9 in which the author has found the necessary and sufficient condition for the validity of Leibnitz's rule in the case of a function which is of bounded variation in accordance with M. Tonelli's definition and the notion of integration used is that of Lebesgue,

A NOTE ON THE INFLUENCE OF LYOPHILIC COLLOIDS ON THE WETTABILITY OF NAPATHALINE.

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SUMMARY

In order to find out the real nature of protective action of lyophilic Colloids, a systematic examination of their physical properties and their relation with each other has been undertaken. In this paper the wettability effect of the so-called protective Colloids has been investigated. This effect has been compared to their protective action as measured by their "Gold number".

The Colloids chosen were gelatine, agar-agar, Casein, wheat-starch and Silicic Acid. The wettability of Napathaline by the above Colloids was determined by a method evolved in Berlin (Dissertation T. H. Berlin, 1933 and Kolloid Beihefte 38. 1. 1933). The results obtained showed that the Colloids examined give the following series when arranged in descending order of their wettability-effect.

Gelatin > Casein > Starch : Agar-agar > Silicic Acid.

The above series was compared with the series obtained when these Colloids are arranged according to Zsigmondy's gold number which is a measure of their protective action. According to descending order of the gold number we get the following series:—

Gelatine > Na Casianate > Potato starch > Silicic Acid.

We find a great resemblance between the two series indicating that wettability and protective action go hand in hand.

It is a known fact that certain lyophilic Colloids such as soap, proteins, etc, lower the surface tension of water remarkably¹. It has been shown in a previous paper², that solutions of the so-called capillary-active substances such as the fatty acids, saturated alcohols and similar other series, possess the property of wetting chemicals which are not wetted by pure water alone. Therefore, it is of importance to know if the lyophilic Colloids that lower the surface tension of water remarkably, can also wet Chemicals which are not wetted by water. Further, it may be possible to find out the real nature of the protective

action of these lyophilic Colloids by a study of the relation between their capillary-active properties on one hand, and other physical properties such as wettability, protective action, etc., on the other.

The Colloids chosen were gelatine, agar-agar, Casein, wheat-starch and Silicic acid. The Chemical of which the wettability was determined was Napthaline. Pure Napthaline was carefully powdered and then divided into particles of various sizes by means of a series of shives. That portion of the Napthaline powder, the diameter of the particles of which was between 0,08-0,2 mm, was taken. 0,3 gm of such a powder was added to 15 cc of the solution of the lyophilic Colloid in a glass tube at about 20° C. After 10-15 sec. the portion that fell to the bottom of the tube without shaking was separated and weighed. The wettability is proportional to the percentage of the powder that falls to the bottom³.

The following results were obtained.

Table I.

NAPHTHALINE AND GELATINE

| Cone. of Gelatine solution. | Percentage of Naphthaline that sunk to the bottom. |
|-----------------------------|--|
| 2,5 | 74,1 , 73,1 |
| 0,5 | 73,5 , 74,1 |
| 0,1 | 74,4 , 74,6 |
| 0,05 | 76,0 , 74,0 |
| 0,025 | 73,6 , 74,5 |
| 0,01 | 50,1 , 51,1 |
| 0,005 | 31,3 , 27,9 |
| 0,0025 | 22,1 , 21,7 |
| 0,001 | 9,0 , 9,3 |
| 0,0005 | 6,2 , 5,8 |
| 0,0 water | 6,2 , 5,6 |

Table II.

NAPHTHALINE AND CASIEN

| Cone. of Casien. | Percentage of Naphthaline that sunk to the bottom. |
|------------------|--|
| 0,44 | 74,7 , 71,5 |
| 0,2 | 70,0 , 74,0 |
| 0,1 | 68,2 , 72,3 |
| 0,05 | 41,6 , 41,9 |
| 0,025 | 33,2 , 37,5 |
| 0,01 | 25,7 , 26,2 |
| 0,005 | 11,3 , 13,4 |
| 0,0025 | 6,3 , 5,9 |
| 0,0 water | 5,8 , 6,2 |

Table III.

NAPHTHALINE AND WHEAT STARCH

| Cone. of wheat starch | Percentage of Naphthaline that sunk to the bottom. |
|-----------------------|--|
| 0,34 | 47,3 , 43,9 |
| 0,13 | 20,9 , 22,6 |
| 0,065 | 13,5 , 14,6 |
| 0,0325 | 10, , 9, |
| 0,0165 | 6,9 , 5,3 |
| 0,0 water | 5,6 , 6,2 |

Table IV.

NAPHTHALINE AND AGAR-AGAR.

| Cone. of Agar-Agar | Percentage of Naphthaline that sunk to the bottom. |
|--------------------|--|
| 0,1 | 37,0 , 35,5 |
| 0,05 | 25,9 , 26,0 |
| 0,025 | 11,2 , 13,2 |
| 0,01 | 6,7 , 5,5 |
| 0,0 water | 6,4 , 5,7 |

Table V.

NAPHTHALINE AND SILICIC ACID

| Cone. of Silicic Acid. | Percentage of Naphthaline sunk to the bottom. |
|------------------------|---|
| 2,5. | 20,0 , 24,7. |
| 1,0. | 6,9 , 4,2. |
| 0,0. water. | 6,4 , 5,6. |

If we compare the concentration of the various Colloids from the above tables that produce no wettability or in other words which produce the same wettability as pure water, we find the following results:—

| Name of the Colloid. | Cone. producing no wettability |
|----------------------|--------------------------------|
| 1. Gelatine. | 0,0005 %. |
| 2. Casein. | 0,0025 %. |
| 3. Starch. | 0,0165 %. |
| 4. Agar-Agar. | 0,01 %. |
| 5. Silicic Acid. | 1,0 %. |

From the above table, it is apparent that if we arrange the Colloids in descending order of their wettability-effect, then we get the following series:—

Gelatine > Casein > Starch : Agar-Agar > Silicic Acid.

If the above lyophilic Colloids are arranged according to Zsigmondy's gold number, we get the following series:—

Gelatine > Na Casianate > Potato Starch > Silicic Acid.

By comparing the above two series, we find a very great resemblance which can hardly be taken to be accidental. Thus it appears that the two properties ; wettability and protective action go hand in hand at least in the case of the lyophilic Colloids under examination.

Further work is in progress in this laboratory to find out the real cause of this similarity.

Reference

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2. Weber and Chatterji, Kolloid Beihefte 38, 1, 1933.
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THE MATHEMATICAL THEORY OF A NEW RELATIVITY

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CHAPTER XIV

THE ROTATIONAL MECHANICS

Introduction

1. There can be two, and only two conceivable explanations of the transmission of light energy through space—first a corpuscular conception that swarms of material particles travel with a high velocity and second, an aether conception that an all-prevading medium vibrates and transmits its undulations with the velocity due to its elasticity.

2. (i) Newton's corpuscular theory broke down because it failed to explain the phenomena of interference, diffraction and polarisation.

(ii) Huygen's wave theory presupposed the existence of an aether and fails to explain many phenomena like scintillation and Compton effect. There are two fatal objections to it, (a) the waves must scatter away at long distances, and yet short waves continue to possess a quantity of energy independent of the intensity ; (b) as pointed out by Poincaire in his *Electricite et Optique* an impossible result follows from treating electro-static forces as a medium of tension in the direction of the electric field and pressure at right angles to it, namely, when the medium is in equilibrium the displacement due to elasticity should be infinite, a *reductio ad absurdum*.

(iii) The modern conception of denying the existence of both matter and medium is an impossible one. Without matter or medium, the propagation of waves is utterly meaningless. We may evade the question by saying that we can actually observe only one effect at a time, but a scientific theory should enable us to comprehend the actual process even though we do not make any

observation at all. The Wave Mechanics certainly gives good results, but fails to give any explanation how light can have both a particle and a wave effect simultaneously. Nature exists without the observation of man, and the human mind ought to be able to comprehend the nature of light, whether actually observed or not. It is the great claim of Quantum Mechanics that it deals with observables only i.e. different states of a body. But the aim of Science should be not only to see a body in two different and independent states, but also to comprehend how the body passes from one state to the other. A moving system may have a specific stable position, and no intermediate stable position; but it must necessarily pass through all the intermediate positions. Any theory which cannot present the various stages through which the system must pass, when undisturbed by observation, but merely postulates that Nature acts by jumps and is discontinuous, must remain unsatisfying. It may be that we observe only the statical effect of a swarm of discreet units and do not follow the track of isolated discreet units. But we must be able to understand how each discreet unit progresses before the theory can be said to represent reality. The modern theory involves self-contradictions like infinite waves suddenly converging to a point and not scattering away, or a single indivisible photon passing through two holes and interfering with itself. There are two fatal objections to it: (a) howsoever much we may console ourselves by saying that the imaginary waves are waves of probabilities or mere waves of partial knowledge or ignorance, we must in our heart of hearts know that what we say is utterly meaningless, if neither matter nor medium exists, (b) in order to express the interaction of n electrons, the wave equation has to represent an imaginary wave propagation in a space of $3n$ dimensions, where n may be a million or more.

3. Both the the wave and the particle aspects can be made intelligible if to the corpuscular character of light a periodic transverse motion of the swarm could be added. Such a theory was published by me in 1933, and is now presented in a mathematical form; but *it is not claimed that in its early stages the theory is either perfect or comprehensive*. At present, it mainly indicates a new line of advance, promising to get us out of the *impasse*.

The essence of it is that the existence of discreet units is the reality, and the conception of waves is a misinterpretation of Nature, being nothing but a mere mathematical effect. Although a swarm of discreet particles cannot ordinarily interfere with one another, a beam of such particles can

produce a wave-effect, if either (i) each particle is a binary system with its components revolving round each other;

or (ii) if the particles, though single units, are emitted from a rotating source.

Section I

THE ROTATIONAL THEORY OF LIGHT

Before dealing with rotational motions mathematically, it would be convenient to state the fundamental basis of the Theory. Newton believed that light consists of material corpuscles, which are herein called "radions". There is only one slight addition made to this conception, which, it is submitted, is simple and natural.

THE SOLITARY ASSUMPTION.

EACH LIGHT CORPUSCLE OR RADION IS INTERNALLY A BINARY SYSTEM, CONSISTING OF TWO COMPONENTS OF EQUAL AND OPPOSITE CHARGES ROTATING ROUND EACH OTHER.

NECESSARY DEDUCTIONS

1. Such an electromagnetic system is a stable system which must propagate itself forward with the velocity of light, the plane of its orbit always remaining parallel to itself.

2. Although each radion, when emitted from a source travels in a straight line, a swarm of radions successively emitted from the source rotating in its orbit, when seen along a particular direction, is effectively equivalent to a stream of radions travelling outwards with a spiral motion along a screw or helix round an elliptical cylinder corresponding to the orbit, and with the same period of rotation.

Section II

INTERFERENCE OF BINARY RADIONS.

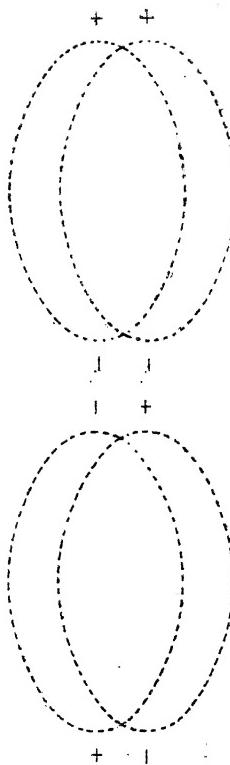
1. As a light radion consists of two components almost close together with extremely small masses but equal and opposite charges, it will rotate round the common centre of gravity and possess great stability. If two such systems have nearly the same phase, the positive and negative charges will respectively strengthen each other and the intensity of light would be increased. But if there be a difference of π between their phases, the effect will be almost nullified, causing interference. Hence if half of a beam of monochromatic light were to lag behind the other half by an odd multiple of that phase difference, there will be a complete interference. Thus the serious difficulty in comprehending how corpuscles can destroy each other is overcome by the composite character of each.

2. For a circular orbit if the disturbance caused by the positive component the *poson* be represented by

$$\eta = a \sin (wt + a)$$

then that due to the negative component the *negon* will be

$$\begin{aligned}\eta' &= -a \sin (\pi + wt + a) \\ &= a \sin (wt + a)\end{aligned}$$



Thus they together contribute to the total effect, half and half.

The fact is that looked at from the centre there are charges of opposite signs moving in opposite directions at the ends of a diameter, and the field produced by them will be similar to that of two dipoles at right angles to each other. When the masses are equal, the orbit is circular.

Section III

THE SPIN OF RADIONS.

In the general case the two components of a radion i.e. negon poson and with equal and opposite charges and unequal masses will rotate periodically in an ellipse round the common centre of gravity, which will be moving parallel to the Z-axis with velocity c .

The equations of motions of each component can be expressed as

$$x = A + A' \cdot \sin \frac{2\pi}{\lambda} (ct + \alpha)$$

$$y = B + B' \cdot \sin \frac{2\pi}{\lambda} (ct + \beta)$$

$$z = C + ct + C' \cdot \sin \frac{2\pi}{\lambda} (ct + \gamma),$$

where A, B, C are constants depending on the position of the centre, A', B', C' , are constants depending on the dimensions of the orbit and the inclinations of the plane of the orbit to the planes of reference; and α, β, γ are constants depending on the phase differences; and λ represents the wave length of the rotational motion, t denotes absolute time, and c is the velocity of propagation parallel to Z .

Section IV

THE DERIVATION OF MAXWELL'S EQUATIONS.

When a light radion consists of rotating positive and negative charges, the electromagnetic effect of the combined binary system becomes obvious.

(1) As an assemblage of binary radions must contain only pairs of posons and negons, a volume of radions would have zero electric density. Hence $\text{Div. } E = 0$.

(2) But the magnetic force is merely the transverse effect of a moving charge, and is therefore round a completely closed curve. Accordingly no isolated magnetic pole can exist in nature. Hence $\text{Div. } H = 0$.

Maxwell's equations of motion accordingly follow as a matter of course.

The wellknown relations are

$$\text{Curl } E = - \frac{\mu}{c} \frac{\partial H}{\partial t} \quad \text{and} \quad \text{Curl } H = \frac{k}{c} \frac{\partial E}{\partial t}$$

$$\text{These give } \frac{\mu k}{c^2} \frac{\partial^2 \alpha}{\partial t^2} = \nabla^2 \alpha \quad \text{and} \quad \frac{\mu k}{c^2} \frac{\partial^2 P}{\partial t^2} = \nabla^2 P$$

Thus in its transverse section, light appears to be an electromagnetic phenomenon in which the electric and magnetic forces are perpendicular to each other, and in the plane at right angles to the line of propagation,

Section V.

THE ELECTROMAGNETIC EFFECT.

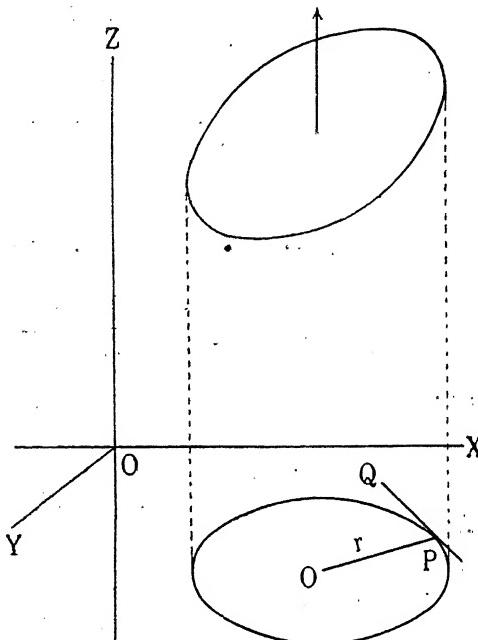
1. The swift rotations of the positive and negative components of a radion round the common centre of gravity would be like electric currents flowing along the elliptical orbit, but in opposite directions.

The magnetic field is nothing but the transverse effect produced by the moving charge. If we take a cylindrical pencil of light, consisting of a large number of binary radions, revolving in all sorts of elliptical orbits, all travelling parallel to the Z -axis, their effect on a cross-section at right angles to the forward path will be the resultant effect of their projections on an XY plane. The projections of the radionic orbits will be ellipses with different inclinations to the two axes

2. We shall first consider the simple case where the two

components (the poson and the negon) are revolving round each other in circles. The electric forces between the positive and the negative charges will be only along the rotating diameter joining them, and neither along the tangent to the orbit nor normal to its plane.

For a region free from charges, Maxwell's electromagnetic equations in cylindrical co-ordinates (r, θ, z) with electric and magnetic components P, Q, R , and α, β, γ respectively, where $Q = R = 0$, and from symmetry round the axis $\frac{\partial}{\partial \theta} = 0$, give



$$\left. \begin{array}{l} -\frac{\partial \beta}{\partial z} = \frac{k}{c} \frac{\partial P}{\partial t} \\ \frac{\partial \alpha}{\partial z} - \frac{\partial \gamma}{\partial r} = 0 \\ \frac{1}{r} \frac{\partial (\beta r)}{\partial r} = 0 \end{array} \right\} \quad \left. \begin{array}{l} 0 = -\frac{\mu}{c} \frac{\partial \alpha}{\partial t} \\ \frac{\partial P}{\partial z} = -\frac{\mu}{c} \frac{\partial \beta}{\partial t} \\ 0 = -\frac{\mu}{c} \frac{\partial \gamma}{\partial t} \end{array} \right\}$$

$$\left. \begin{array}{l} \frac{1}{r} \frac{\partial}{\partial r} (rP) = 0 \\ \frac{1}{r} \frac{\partial}{\partial r} (\alpha + \frac{\partial \gamma}{\partial z}) = 0 \end{array} \right\}$$

(See Weatherburn's Vector Analysis §§. 12 & 125) These yield

$$\frac{k}{c} \frac{\partial^2 P}{\partial t^2} = -\frac{\partial}{\partial t} \frac{\partial \beta}{\partial z} = -\frac{\partial}{\partial z} \frac{\partial \beta}{\partial t} = \frac{c}{\mu} \frac{\partial^2 P}{\partial z^2}$$

$$\therefore \frac{\partial^2 P}{\partial t^2} = \frac{c^2}{k\mu} \frac{\partial^2 P}{\partial z^2},$$

$$\text{Similarly } \frac{\partial^2 \beta}{\partial t^2} = \frac{c^2}{k\mu} \frac{\partial^2 \beta}{\partial z^2}.$$

This is a wave propagation along the Z-axis with velocity $\frac{c}{\sqrt{k\mu}}$ without any further assumption.

$$\text{Also } \frac{\partial \alpha}{\partial t} = \frac{\partial \gamma}{\partial t} = 0.$$

So α and γ are independent of time, and therefore they do not really enter into the wave equation.

And rP and $r\beta$ are independent of r , and owing to the symmetry round the centre, independent of θ also.

$$\text{Hence } P = \frac{A}{r} \quad \text{and} \quad \beta = \frac{B}{r},$$

where A and B are functions of time only.

Also $\frac{\partial \alpha}{\partial z} = \frac{\partial \gamma}{\partial r}$, a particular solution of which is $\alpha = \gamma = 0$, which is physically quite plausible,

As the positive and negative charges are rotating in the same direction, their righthanded and lefthanded effects would cancel each other on the average, and there will be no net magnetic force along the normal to the plane. When the charges are at opposite ends, α must necessarily be zero.

3. If the orbit is elliptical then $\frac{\partial}{\partial \theta} \neq 0$.

Accordingly

$$\left. \begin{aligned} \frac{1}{r} \frac{\partial \gamma}{\partial \theta} - \frac{\partial \beta}{\partial z} &= \frac{k}{c} \frac{\partial P}{\partial t} \\ \frac{\partial \alpha}{\partial z} - \frac{\partial \gamma}{\partial r} &= 0 \\ \frac{1}{r} \frac{\partial(\beta r)}{\partial r} - \frac{1}{r} \frac{\partial \alpha}{\partial \beta} &= 0 \end{aligned} \right\} \quad \left. \begin{aligned} 0 &= -\frac{\mu}{c} \frac{\partial \alpha}{\partial t} \\ \frac{\partial P}{\partial z} &= -\frac{\mu}{c} \frac{\partial \beta}{\partial t} \\ -\frac{1}{r} \frac{\partial P}{\partial \theta} &= -\frac{\mu}{c} \frac{\partial \gamma}{\partial z} \end{aligned} \right\}$$

$$\left. \begin{aligned} \frac{1}{r} \frac{\partial}{\partial r} (r P) &= 0 \\ \frac{1}{r} \frac{\partial}{\partial \theta} (\alpha r) + \frac{1}{r} \frac{\partial \beta}{\partial \theta} + \frac{\partial \gamma}{\partial z} &= 0 \end{aligned} \right\}$$

$$\text{Hence } \frac{k}{c} \frac{\partial^2 P}{\partial t^2} = \frac{\partial}{\partial t} \left\{ \frac{1}{r} \frac{\partial \gamma}{\partial \theta} - \frac{\partial \beta}{\partial z} \right\}$$

$$= \frac{c}{\mu} \frac{1}{r^2} \frac{\partial^2 P}{\partial \theta^2} + \frac{c}{\mu} \frac{\partial^2 P}{\partial z^2}$$

which will be a wave equation with velocity $\frac{c}{\sqrt{\mu k}}$ along the Z-axis if

$$\frac{\partial^2 P}{\partial \theta^2} = 0$$

or

$$P = A_1 + B_1 \theta$$

where A_1 and B_1 are constants with respect to θ only and may be functions of r and t .

But as $\frac{\partial}{\partial r} (r P) = 0$, it follows that rP is independent

of r .

Hence $P = A + B\theta$, where A and B are functions of time only.

4. Corrections for the rotating charged components of the radion will be considered later.

5. (1) As the opposite charges are always at the ends of a diameter, there would naturally be electric force along it, the radial value of which for a whole revolution may be denoted by P.

(2) In spite of the fact that the charges are rotating there must be an electric intensity between them. But there is no reason why there should be any electric force at right angles to the diameter joining them, nor any reason for there being a force at right angles to their plane.

(3) In the case of material particles like a hydrogen atom, the electric force is $\propto e^2/r^2$ and they do not blow off. In the case of light, subject to Maxwell's equations, the force is $\propto e^2/r$, which necessitates the radions travelling forward with the velocity of light.

6. THE SPECTRAL SHIFT.

If V be the forward velocity, T the period of rotation and λ the wavelength, then $\lambda = VT$, which is the axial distance travelled in one revolution.

Hence as the Sun's gravitation cannot change T , but only affects V ,

$$\frac{\lambda_s}{\lambda_e} = \frac{V_s}{V_e}$$

From this relation the results of Ch. XIII Sec. IV follow.

The method adopted in Einstein's Relativity of making a wholly arbitrary and really fallacious assumption that radiating solar atoms are "momentarily at rest" is open to a fatal objection. As every atom must, in addition to its own intrinsic velocity, possesses a high radial velocity, if not also in some cases a transverse velocity as well, the assumption is altogether an impossible one.

7. THE DEFLECTION OF LIGHT.

When light consists of material corpuscles i.e. radions, the bending of light owing to the gravitation of the Sun becomes obvious.

8. THE SUPPOSED EXPANSION OF THE UNIVERSE.

(i) For circular rotations $P = \frac{A}{r}$, where P is a function of time

only. If w be the angular velocity and m the revolving mass, then

$$\frac{A}{r} = mr\omega^2, \text{ where } T = \frac{2\pi}{\omega}$$

From the angular momentum's approximate constancy,

$$mr^2\omega \text{ is constant.}$$

Hence $P \cdot T$ is constant.

(ii) If with lapse of time there is an exchange of some part of the charges between the positive and the negative components, then the force will decrease, and so the period will increase. It is therefore obvious that as time elapses, the periodic time will tend to obey the Proportionality to Linear Distance law. There is accordingly an inherent diminution of frequency with passage of light through space, explaining the supposed expansion of the Universe. For the spuriousness of the recessional velocities of nebulae see also Ch. III pp. 227-9. (Jan. 21, 1935)

If the formation of the swarm is as is shown in the next Section VI, then the increase of period and therefore the loss of frequency with the distance travelled will take place as shown in Ch. II Sec. III, pp. 27-8.

9 The binary system has some similarity to J. J. Thomson's theory of circular lines of electric rings travelling at right angles to their planes.

(Nature, Vol. 137, pp. 232-3, Feb., 8, 1936)

He takes $P = R = 0$.

Then Maxwell's equations give

$$\mu\kappa \frac{\partial^2 Q}{\partial t^2} = \frac{\partial^2 Q}{\partial z^2} + \frac{\partial}{\partial r} \left\{ \frac{1}{r} \frac{\partial}{\partial r} (rQ) \right\}$$

This equation cannot possibly represent a wave propagation unless

$$\frac{\partial}{\partial r} \left\{ \frac{1}{r} \frac{\partial}{\partial r} (rQ) \right\} = 0$$

for which the solution is of the form $Q = A r + \frac{B}{r}$, which makes Q infinite both at the centre and at ∞ . The latter is an impossible result.

Section VI

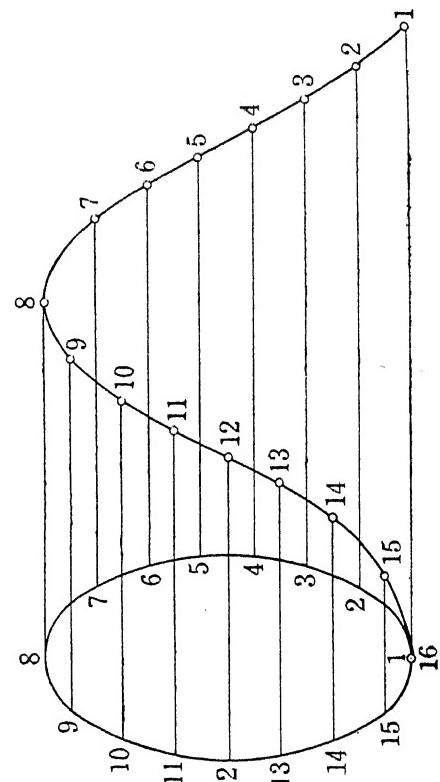
THE WAVE EFFECT OF A SWARM OF PARTICLES FROM A ROTATING SOURCE

1. Let a radiating source revolve in an elliptical orbit in an anti-clockwise direction occupying the positions, 1, 2, 3, etc. at units of time 1, 2, 3, etc. (may be after many revolutions), and let it emit one radion at each of these positions in the direction of a z -axis at intervals of t . Then at any instant of time, the distance travelled by the first radion will be ct more than that by the second and so on. By marking the positions which they all would attain at this instant it will be seen that although every radion has travelled in a straight path parallel to the Z -axis, the whole group has assumed a spiral formation, like the thread of a screw round the cylindrical pencil. The group will continue to travel forward in this set formation.

If a plane be placed at right angles to the axis of the cylinder, the effect of the swarm of radions impinging on this section will be as if there were a shower of rain falling on it, each radion possessing a momentum and causing pressure. The swarm when observed in this way will have a particle aspect.

On the other hand, the effect in the plane section when successive radions reach it will be that of disturbances moving along elliptical orbits, as if produced by a transverse rotatory motion. The effect in this section will be periodic. The swarm when observed in this way will have a wave aspect.

Thus the swarm possesses both the particle and the wave aspects simultaneously, without any contradiction; and either one or the other is



observed according as we observe the effect of the swarm perpendicular to or in the plane section. The picture illustrates the motion of such revolving radions which also will possess both these aspects. In all experiments in which the effect as observed is the result of motion along the path (e.g. scintillation or Compton effect) the swarm will behave like a shower of bullets; whereas in all experiments in which the effect is seen at right angles to the path of light, (e.g. interference or polarisation) the swarm will behave like a wave propagation.

2. *Illustration.* The motion can be clearly illustrated if the nozzle of a rubber tube attached to a water reservoir be made to rotate in an ellipse while water is flowing through it with some force. Although each drop of water, after leaving the nozzle really travels in a straight line, the stream of water as a whole will appear to travel forward in the form of a helix, the period of rotation of the nozzle and the velocity of the flow of water determining the wave length of the screw motion, $\lambda = V.T.$

3. It is obvious that even if the axis of the cylinder parallel to which the light travels be not at right angles to the plane of the source's orbit, but inclined to it, the axial length of one complete revolution will still represent the longitudinal distance travelled by light during one complete rotational period of the source. Hence the wave length of the swarm of radions from revolving sources is wholly independent of the inclination of the orbit to the path of light and depends on its period only. The inclination of the orbit to the path will merely affect the size of the screw, the dimension diminishing as the inclination increases. A change in the direction of rotation will, however, change a right-handed screw to a left handed one, and vice versa.

4. Such a swarm of particles emerging from a rotating source is the exact equivalent of a stream of radions travelling forward in a screw motion.

The wave function can be expressed as

$$\psi = A \sin \frac{2\pi}{\lambda} \left\{ ct - (lx + my + nz) \right\}$$

This can be put more generally as

$$\psi = A e^{\frac{2\pi i}{\lambda}} \left\{ ct - (lx + my + nz) \right\}$$

representing a plane wave in the r direction.

This fulfils the differential equation

$$\nabla^2\psi = \frac{1}{r^2} \frac{\partial^2\psi}{\partial t^2}.$$

5. Now experiment with light pressure has established that the heat (which stands for energy) carried by light is equal to its momentum multiplied by its velocity.

Accordingly, $E = \mu c \times c = \mu c^2$, where μ stands for the mass of a radion. This is similar to Einstein's postulate for matter. If r and ω be the radius vector and the angular orbital velocity of the whirling radion, then the energy is also

$$E = \frac{1}{2}\mu c^2 + \frac{1}{2}\mu r\omega^2, \quad \text{as the radion's}$$

potential energy in the orbital motion is zero when its total charge is nil. Accordingly $c = r\omega$.

$$\text{Hence } E = \mu c^2 = \mu r^2 \omega^2 = (\mu r^2 \omega) \omega = \frac{h}{2\pi} \frac{2\pi}{T} = h\nu.$$

6. THE SPECTRAL SHIFT

(1)

In this formation, gravitation will not affect the wavelength, but only the velocity. Hence $\frac{T_s}{T_e} = \frac{V_s}{V_e}$. Thus if wavelength is measured inversely as the frequency, the result is the same as before.

(2) If the solar atoms be travelling outwards radially with velocity v , then the correction to be introduced on account of the Doppler Effect as in Chapter IV, p. 236 is $-\frac{v}{c} \cos \alpha$, where α is the angle between the radius of the Sun and the line of sight.

The correction due to the angular velocity ω of the Sun is

$$\frac{a\omega}{c} \cdot \sin(\pm \alpha)$$

A FORECAST

1. A beam of light consists of a swarm of discrete radions so far apart as to make the interaction of their respective components, (the posons and negons), with one another negligible.
2. The differences between red rays, violet rays, X rays, and γ rays if not also cosmic rays consist solely in their successively quicker rotations i.e. their frequencies.
3. A group of radions so close together that their respective components interact with one another forms matter. Positrons, electrons or neutrons are formed respectively when either one poson or one negon is in excess, or they combine in equal numbers.
4. If the structure of a radion be similar to that of a hydrogen atom, i.e., mass of the negon negligible as compared to that of the poson, then the total angular momentum of a system composed of a number of posons will always be an integral multiple of that of a radion. This would correspond to Bohr's first assumption.
5. In a stable rotational system the average of any function of the coordinates or their differentials for the whole constant period will remain constant. This will give Sommerfeld's quantum conditions.
6. If a radion is lost by a rotating source, then the elements of the instantaneous orbit will be changed, diminishing the major axis and the latus rectum and also the angular momentum, and therefore producing a new orbit, without any jump, thus establishing a continuity and not a discontinuity in nature.

APPENDIX TO CHAPTER XIV

The Unified Theory of Physical Phenomena

In order to explain interference, diffraction and polarisation it is necessary to impart to the particle character of light a transverse periodic motion. This idea was the basic foundation of the Rotational Theory of light which was Part II of the more general "Unified Theory of Physical Phenomena" published by me in 1933 (Empire Press, Allahabad) a brief abstract of which is given below with references to its pages:-

(1) *Screw motion* (pp. 21-3). It is quite reasonable to suppose that a light particle or radion has a structure similar to that of a planet revolving round the sun i.e. a binary system, possessing, in addition to its forward translational motion, a rotational motion as well. The combined rotational motion and the translational motion would give to each component of the radion a screw-wise motion, and make the curve of its path a sort of a helix or spiral. For example, the path described in space by a component of a radion may be along a piece of thread tightly wound round the curved surface of an elliptical cylinder. It will possess both a rotational velocity and a translational velocity.

(2) *Wave motion*—(p. 25).—Its motion seen (1) along the axis, would be simply a forward motion with velocity c . (2) as a projection on a section at right angles to the axis, would be a transverse elliptical motion resolvable into two simple harmonic motions at right angles to each other, with a common period, though with different amplitudes and phases, and (3) in a plane containing the axis, a wave motion. The amplitude will vary periodically, with a maximum and a minimum, while the latitudinal projection of the path is an ellipse, the longitudinal projection will be in the form of a wave, with crests and troughs.

(3) *Wavelength, Period and Frequency*—(p. 26)—Let c be the forward translational velocity of the radionic system, T the complete period of rotation and λ the distance travelled along the axis with velocity c during a complete revolution. Then $\lambda = c \cdot T$. Thus the wavelength would be the axial distance travelled lengthwise during one complete revolution. The frequency would obviously be the number of revolutions round the axis per second.

(4) *Conservation of Momentum*—(p. 23)—As its linear momentum must be constant, its forward velocity will remain constant. And as its angular momentum must be constant, the period of rotation must remain constant and the rate of describing the sectional area must be constant.

i.e. $m.r.\frac{rd\theta}{dt} = \text{constant} = mh = m \cdot \frac{2\pi ab}{T}$, where a and b are the semi-axes and T is the period of revolution.

(5) *Constant Periodic Time*—(p. 24)—It is the permanence of the periodic time, which characterises light. Monochromatic light is a swarm of radions, possessing the same period, hence having the same wavelength and frequency. (Light emitted from atoms rotating with same period will possess the same period).

(6) *Intensity*—(p. 24).—The intensity of light merely depends on the number of light radions moving along the path of the beam per unit area per unit of time.

The intensity of a pencil of light particles depends on the rate at which energy travels normally across a unit area per unit time i.e. \propto velocity and square of amplitude.

(7) *Filling of Space*—(p. 36).—As every source of light that we see has a finite size, and radions emerge from all points in it, the emissions from all points cross each other, resulting in a sort of mesh work. Accordingly even though the distance may increase, there are no finite interspaces completely free from radions, and, therefore, the source is visible from all angles.

(8) *Spectrum Colour*—(pp. 28-9).—Difference in colour is due to the difference in the rotational period of the radions. The violet rays spin faster round the axis of the path, have shorter periods of revolution, and therefore shorter wavelengths; but as they perform greater revolutions per unit time, they have higher frequency than

red rays. The latter have a longer period and so take a longer time to complete a revolution and their rotational speed is slower, their wavelength, the longitudinal distance travelled during a revolution, is longer, but the revolutions per unit time being fewer, their frequency is lower. Thus light rays from the ultra violet to the infra red range in the spectrum are arranged merely in their descending order of rotational speed, i.e. the number of revolutions per unit time that they make round the axis of the path, in other words in the order of their decreasing frequency and therefore ascending wavelengths and period.

All radions have one constant forward velocity. "The radions which during the time of travelling round the cylindrical path owing to their slow rotational motion cover a longer distance forward in one revolution as the forward velocity is the same have correspondingly longer wavelengths—these are infra-red. Those which in one revolution cover a shorter distance have shorter wavelengths. These are ultra violet. The latter have quicker rotational motion than the former."

(9) *Reflection*—(p. 33)—On a particle theory, reflection of light as a result of collision with atoms admits of a simple explanation. If the medium remains unchanged, the longitudinal velocities remain unaltered and so the different rotational velocities of light of various frequencies do not produce any divergence of the rays, and accordingly no spectrum is seen.

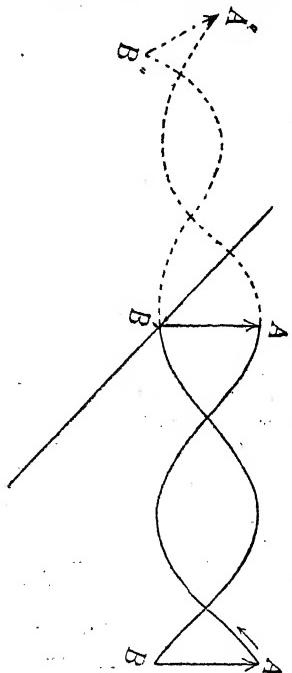
(10) *Cavity Radiation*—(pp. 35-6)—The radions inside a cavity will be reflected and re-reflected over and over again, finding it difficult to emerge. The cavity thus behaves like a black surface, absorbing the radions and not reflecting them. If they do ultimately emerge, their speed of rotation would then have been diminished considerably by the collisions. They will accordingly get reddened.

(11) *Refraction*—(pp 30-1)—The greater bending of light in a denser medium broke down Newton's corpuscular theory. But this phenomena is explicable on a rotational theory.

First consider a small image shown by a small arrow travelling forward and meeting an inclined surface of a dense medium. The base enters first and its velocity is immediately reduced. The top travels with the former velocity and then enters, after which the entire image travels with reduced velocity. The necessary result of the lower portion getting its velocity reduced earlier than the upper portion is to turn the image round, so that the axis perpendicular to the image is bent towards the normal to the separating surface.

Next consider the two components of a radion revolving in an orbit (i.e. two almost massless particles revolving like binary stars). A complete revolution is performed during the time when the distance of a wavelength is covered in the forward velocity. It follows that during this period one component of the radion would still remain outside the separating surface while the other has gone inside the medium. The forward velocity of the latter is reduced inside the thicker medium, but not that of the one outside. The necessary result is that the plane of rotation is bent, and the axis inclined towards the normal to the surface. The direction of forward motion perpendicular to the transverse vibration is therefore inclined towards the normal. The mutual attraction of the two binaries causes a bending of the path of their propagation.

(12) *Refractive Index*—Not only Newton's corpuscular theory failed to explain refraction because he wrongly assumed the horizontal velocity to remain constant, but



even the wave theory also, without another dispersive theory, failed to explain why violet rays with shorter wavelength should bend more than red rays. But on the rotational theory, there being a greater tangential velocity for higher frequency rays, the resistance of the medium reduces the velocity more than in the case of rays not moving so fast. As shorter wavelengths revolve a much greater number of times while a unit length is travelled they meet with greater resistance owing to the collision with the atoms of the medium, than if fewer revolutions occur during that interval. Hence rays of shorter wavelength are refracted more than those of longer wavelength.

(13) *Scattering*—(p. 33)—The same consideration explains a greater scattering for violet rays than for red. Rays which rotate faster during a unit time are bound to have more elliptical orbits per unit distance and must therefore collide against atoms much more than rays with fewer revolutions would do per unit time. This explains Rayleigh's scattering and the blue of the sky.

(14) *Penetration*—(p. 32)—The classical theories offer no explanation why X-rays, γ -rays and cosmic rays should penetrate more than waves of lower frequency. On the rotational theory it is obvious that a fast rotating screw will pierce further than a slow rotating one. Although the intensity will diminish owing to greater scattering, they will on account of their rapid and inclined motion bore through deeper.

(15) *Pressure*—(p. 36)—The pressure exerted by moving radions by their infringing on a material body is patent.

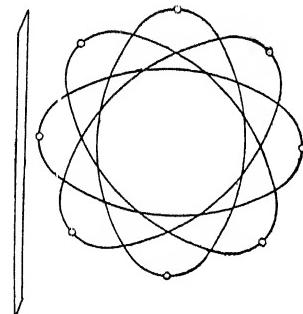
(16) *Absorption*—(p. 38)—It is clear from the principle of resonance that radions would be taken up by an electron of an atom if their periods of revolution are the same. They would not be retained if there is a difference. It follows that elements would absorb the same kind of radions as they would themselves emit when incandescent, because the period of revolution is identical.

(17) *Compton Effect*—(p. 60)—The particle nature of the light radions has been demonstrated by Compton's discovery that photons in their collisions with electrons obey the laws of conservation of energy and momentum, are deflected like billiard balls and are scattered exactly as if they were a swarm of material particles.

(18) *Polarisation*—(p. 37)—The corpuscular theory based on straight motions of corpuscles broke down when polarisation was discovered which required a transverse vibration. On the rotational theory radions possess transverse motions as well.

(a) It is easily intelligible how radions moving in elliptical orbits will be intercepted by a tourmaline crystal except those which have elongated orbits with their major axes parallel to the axis of the crystal. These latter will be completely obstructed by a second crystal if its axis be at right angles to their major axes.

(b) When light radions are pictured as moving in elliptical orbits inclined to the path, those whose orbits are in the plane of the incident and reflected rays will find it easier to pierce through, and indeed for a certain angle of incidence could be completely transmitted

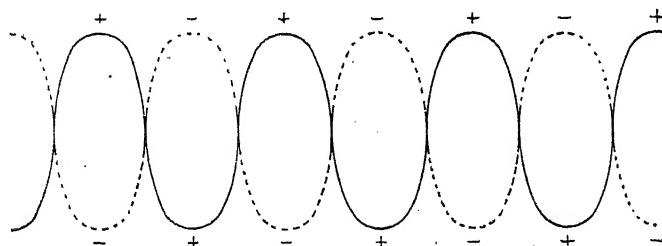


without being reflected, and be polarised. But those whose orbits are perpendicular to that plane will have greater facility for being reflected than refracted. Hence the reflected light will be completely polarised for a certain angle of incidence.

(v) Double refraction is obviously explicable if in an Iceland spar (calcite) the velocity of the refracted ray is different in different directions giving rise to two different refracted rays polarised in perpendicular planes.

(19) *Interference*—(pp. 33-4)—The rotational theory combines the effect of both the corpuscular and wave theories. Light possesses double motion—the longitudinal motion like a particle carrying pressure and scintillation, and the transverse periodic angular motion. The period of rotation being constant, a harmonic motion results. If two parts of a beam meet again after having travelled different distances, a difference in the phase of rotation comes in, which causes interference.

The transverse elliptic motion can be easily resolved into two transverse simple harmonic motions at right angles to each other, with the same period, but different amplitudes and phases.

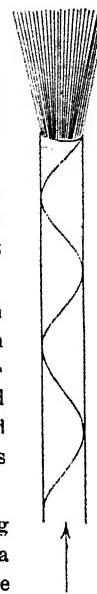


The reason why light from two different slits can not interfere is that every source of light has finite dimensions and light rays from every part of its visible surface come to the slits and get commingled.

(20) *Diffraction*—(pp. 34-5)—Undoubtedly atoms and electrons are discrete units and yet they are now found to be diffracted. It is therefore quite wrong to suppose that it is impossible for particles to be diffracted. All that is necessary is that particles must have a periodic transverse motion, which is obtained in the Rotational Theory. The radions about to emerge from the pinhole owing to their rotational motion collide against the electrons in the atoms at the extremity and are therefore deflected in various directions. The fact that a small obstacle can stop the visibility of a source of light confirms the particle theory. The absence of the exact shadow of a needle or a wire and the presence of blurred edges are the result of the transverse vibration of the radions. Those passing by the two sides behave like light coming from two sources, causing interference.

On the wave theory, it has always been supposed that the effect on the sides away from the main path of light is destroyed. But if each point is a new source of secondary wavelets, then new sources should be taken far away from the hole, and waves will move both backwards and forwards. Hence light ought to bend back and illuminate all space as sound fills all space. The bending should not depend on wavelength only. This difficulty does not arise in the Rotational theory.

(21) *Ionisation*—A rotating radion can produce ionisation by knocking out an electron from an atom. Obviously if a radion is moving with a faster angular velocity, its success in knocking out an electron would be greater than if it be revolving more slowly. Also a faster rotating radion will describe



more revolutions per unit time or per unit distance, and so its chances of hitting electrons would be greater. Hence waves of shorter wavelength, produce greater ionisation than those of longer.

(22) *The Quantum of Light*—(pp. 37-8)—On the particle theory, the existence of photons as separate discreet units is obvious. A definite quantity of energy is associated with each rotating radion, the angular momentum of each rotating radion is Planck's constant \hbar . It follows that additions of energy to an atom imparted by light can be in multiples of $h\nu$ only.

(23) *Zeeman Effect*—(p. 59)—A magnetic field makes the elliptical orbits of atoms become parallel to one another and at right angles to the line of force. If light radions are emitted by the rotating electrons then when seen along the lines of force through cylindrical holes in the poles of the magnet, the projections of the ellipses would be circles and light would be circularly polarised; and the direction of polarisation would be opposite if seen from the North and South Poles. But when seen at right angles to the lines of force, the projections of the circles would be straight lines, and the light will appear to be plane polarised.

(24) *Stark Effect*—(p. 60)—produced by an electrical field is similarly explained.

(25) *The Cosmic rays*—(pp. 61-2)—Light rays, Xrays and Cosmic rays all may emanate from atomic systems, the difference between them consisting in the sizes of the radii of the orbits from which they emerge. The greater penetrating power is due to the greater rotatory motion and their linear momentum, all being material particles.

(26) *The Expanding Universe*—(pp. 60-61)—The rotating light radions can explain the decrease in the angular motion due to collisions with particles of matter, and also due to the pull of heavenly bodies causing an enlargement of the orbits, as light radions pass through space. The reddening of light is accordingly proportional to the distance travelled through space.

NOTE.—A short abstract of the Rotational Theory of Light was also given in the author's Presidential Address to the Academy of Sciences, on January 20. 1934, (Pr. Ac. Sc., III, pp. 358-9).

BUSINESS MATTERS

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PATRON

His Excellency Sir Harry Haig, K. C. S. I., C. I. E., I.C.S.
The Governor of the United Provinces of Agra & Oudh.

HONY. FELLOWS

The Hon'ble Sir J. P. Srivastava, Kt., M.Sc. (Tech).

The Minister of Education,

The United Provinces of Agra & Oudh.

Pandit Madan Mohan Malaviya, LL. D..

Vice-Chancellor,

Benares Hindu University.

BENEFACTOR

The Vice-Chancellor,
Allahabad University, Allahabad.

ANNUAL MEETING

The Annual Meeting of the National Academy of Sciences, India, was held in the Vizianagram Hall, Muir College Buildings, Allahabad, at 3 P. M. on Friday, January 15, 1937. Lt.-Col. R. S. Weir, M. A., B.Sc., I. E. S., M. L. C., Director of Public Instruction, United Provinces, presided over the function. Dr. P. L. Srivastava, M. A., D. Phil. (Oxon), the General Secretary, read the Annual Report of the National Academy of Sciences, India.

Prof. N. R. Dhar, the President of the Academy, gave his address. Lt.-Col. R. S. Weir, then, delivered his address

Sir John Russell, F. R. S., Director of Rothamsted Experimental Station, also delivered an address on some aspects of the agricultural problems of India.

Prof. A. C. Banerji, M. A., M.Sc., I. E. S. proposed a vote of thanks to Lt.-Col. R. S. Weir and Prof. D. R. Bhattacharya Ph. D., D.Sc. seconded the vote,

(i)

SECRETARIE'S REPORT

PRESENTED AT THE ANNUAL MEETING OF THE NATIONAL
ACADEMY OF SCIENCES, INDIA, ON JANUARY 15, 1937.

BY

DR. P. L. SRIVASTAVA.

We have the honour to submit the following report of the working of the Academy during the period beginning from the 20th December, 1935 to the 31st December, 1936. The Fifth Annual Meeting of the National Academy of Sciences, India, was held in the Vizianagram Hall, Muir College Buildings, Allahabad, at 4-30 P. M. on Thursday, December 19, 1935. His Excellency Sir Harry Haig, K. C. S. I., C. I. E., I. C. S., Governor of the United Provinces of Agra and Oudh and Patron of the Academy, presided over the function. Dr. P. L. Srivastava, a General Secretary, read the Annual Report of the National Academy of Sciences, India.

Prof. N. R. Dhar, President of the Academy, read his address. His Excellency Sir Harry Haig then delivered his address.

We are glad to record the steady progress the Academy is making both as regards its membership and the standard of its publications. The Academy has now on its rolls 177 members, of whom 43 are Fellows of the National Institute of Sciences of India. The journal of the Academy has received good recognition in India as well as outside India. The articles published have been highly appreciated and profusely quoted in scientific journals all over the world and have been abstracted in all the important Science Abstracts. We are now receiving 159 Foreign and Indian scientific journals in exchange.

One gratifying event that happened during the year under review was the conferment of the distinction of the fellowship of the Royal Society on our Foreign Secretary, and now the President-elect, Prof. Birbal

Sahni of the Lucknow University. Prof. Sahni is the fifth Indian to receive this signal honour, and we all feel highly proud of him.

The financial position of the Academy has not been quite sound. We are deeply grateful to the Government of the United Provinces of Agra and Oudh for the grant we have been receiving from them for the last several years. We also gratefully acknowledge the grant of Rs. 500/-made to us by the Imperial Council of Agricultural Research, New Delhi, for the purpose of publishing our Proceedings. This grant, we are glad to say, is to continue for three years. In the first year of its existence the Academy of Sciences, U. P., as we were formerly known, received a grant of Rs. 4,000/- and it was in the hope that this grant would be made a recurring one that that Academy began to function. In subsequent years, however, owing to the financial stringency, the Government have been giving us only Rs. 2,000/-per annum. This grant is too meagre for our purpose and we hope that the Government will now be pleased to sanction a recurring grant of Rs. 4,000/-. As for the present year we hope that this sum will be given to us from the savings. We are also grateful to Sir Shah Muhammad Sulaiman, Kt., LL. D., Chief Justice, High Court, Allahabad, for a donation of Rs. 250/-to the Academy.

We have been able to publish four issues of our Proceedings during the year 1936. Although we have increased the number of pages of our Proceedings we have not been able to print all the papers read before the Academy which were found suitable for publication by eminent referees. Unfortunately any attempt to increase the number of pages in any issue of the Proceedings or the number of issues in a year has to be restricted on account of financial difficulties. Although there are many important foreign scientific societies eager to exchange our Proceedings with their publications we are not in a position to send our Proceedings to all of them, as the finances do not permit us to do so. For these reasons again we have not yet been able to organise properly a Science Library. The need for a building of the Academy in which we can house our library, which is rapidly increasing in size, and hold our meetings, is urgently felt. An appeal for raising money for this purpose was addressed to the universities of India, but there was no response. This appeal will be repeated and will be addressed to big industrial concerns of this country and to Indian Princes also, and we shall make sustained efforts to raise funds needed for this purpose. With the help of the Government, the

Indian universities, the industries of this country, the Indian potentates and the generous public we hope it will be possible for us to construct a suitable building for the Academy before long and to have sufficient funds at our disposal to enable us to enlarge our activities.

All the meetings of the Academy have been held at Allahabad this year, but it is hoped, that with the increase in the number of the members of the Academy residing at other academic centres the meetings of the Academy would in future be held in other places as well.

The Education Minister's Gold Medal has been awarded this year to Dr. D. S. kothari, Reader in Physics, Delhi University, his papers having been judged to be the best published in Physics and Engineering in the journal of the Academy.

When we transformed ourselves into the National Academy, we elected, according to our new rules, one hundred Fellows of this body. A perusal of the list will show that our Fellows are persons of great scientific eminence and they hail from every part of the country.

Dr. Hrishikesha Trivedi resigned the post of the Asst. Editor and Mr. Ushanath Chatterji has been appointed Honorary Special Officer in his place.

During the year under review we are sorry to record the deaths of our two distinguished Fellows, namely, Prof. C. A. King and Prof. K. K. Mathur, both of the Benares Hindu University.

Lastly, we wish to express our thanks to the Office-bearers of the Academy and the Members of the Council and to the Special Officer for their ungrudging help and active co-operation.

MESSAGE FROM THE HON'BLE MR. J. P. SRIVASTAVA,
THE MINISTER OF EDUCATION, U. P.

The inauguration of unitary, teaching and residential Universities in these Provinces brought in its train a desire on the part of our scientists to form an association for the cultivation and promotion of science in its various branches. The idea did not take a definite shape till late in 1930 when the Academy of Sciences was duly formed and registered. Such Academies have played an important part in the development of science and stimulation of scientific research in different parts of the world and I feel great pleasure in saying that our Academy has not lagged behind but kept pace with the march of events. The number of works published by the various members of the University under its auspices is evidence of their wide range of scholarship and organized and systematic thinking and the high level of research attained by them has been recognised by savants not only in this country but in Europe and America as well. India was in the past the pioneer in the discovery and dissemination of knowledge and with such stalwarts as Acharya P. C. Ray, Sir Jagdish Chandra Bose, Dr. Meghnad Saha, Sir C. V. Raman and Dr. Birbal Sahni amongst us, we can still hold our head high and rub shoulders with the most advanced nations of the world.

I realise that the Government and the Department of Education have not, owing to financial stringency, been able to do as much for this institution as they wished to do, but I hope with the advent of the new constitution and better days more funds will be forthcoming. I shall watch the progress of this Academy with the keenest of interest and send my very best wishes for its increasing success.

LUCKNOW.

(Sd.) J. P. SRIVASTAVA,

December 22, 1936.

Minister of Education,

United Provinces.

Address of the President

PROF. N. R. DHAR, D.Sc. (Lond. & Paris), F.I.C., I.E.S.,
At the Anniversary Meeting held on 15th January, 1957.

NITROGEN TRANSFORMATIONS IN THE SOIL

Introduction

It is interesting to note that the source from which plants take up their nitrogen was not definitely traced as late as the middle of the last century. Even the great chemist Leibig, whose writings deeply impressed agricultural science and practice in Europe did not realise the importance of supplying nitrogenous manure to the soil as is evident from the following lines taken from his publication in "Farmer's Magazine" 1847 :— "If the soil be suitable, if it contain a sufficient amount of alkalies, phosphates and sulphates nothing will be wanting. The plants will derive their ammonia from the atmosphere as they do carbonic acid."

In my last Presidential Address I emphasised that the problem of supplying nitrogenous manure to the soil is of greater importance in India than in Europe because the nitrogen content of Indian soils is generally half of that present in European soils. Moreover, due to high temperature and sunlight there is greater nitrogen loss from soils in India than in Europe. Regarding the importance of investigations on these problems, the Royal Commission on Agriculture in India (1928) reported as follows :—

"We have been impressed by the importance of research into the fundamental problems connected with the losses in nitrogen and with nitrogen recuperation."

In my last Presidential Address I had the honour of bringing before you our observations showing that molasses can fix nitrogen when added to the soil and can conserve soil nitrogenous matter. Moreover, all carbohydrates, glycerol, cellulosic substances like paper, leaves, saw dust, straw and even cowdung containing cellulose and pentosans, have been found to fix atmospheric nitrogen in soil and conserve the soil nitrogen. As a matter of fact, all energy-rich materials including fats when mixed with soil are oxidized and supply the energy necessary for the fixation of atmospheric nitrogen in soils. With molasses when added to soil in heaps the total nitrogen is readily doubled. Applying 3 tons of molasses (containing 60% carbohydrates) 112 lbs. of nitrogen are added per acre of land in field trials and similarly

using 10 tons of molasses per acre 270 lbs. of nitrogen are fixed. It is believed that symbiotic nitrogen fixation adds 50 to 100 lbs. of nitrogen per acre under normal conditions in temperate countries. As the nitrogen obtained by fixation in soil on the application of molasses is retained in the soil for a much longer time than when ammonium sulphate is added and as the price of molasses is very low, carbohydrate manuring appears to be an excellent proposition for adding nitrogen to tropical soils.

We have investigated various factors which influence the nitrogen transformations and loss in the soil and have been able to elucidate the different stages and the influence of sunlight in the nitrogen transformations in the soil. Our observations lead us to conclude that sunlight plays a prominent rôle in the nitrogen transformations in the soil. In this Address a summary of our results and conclusions is recorded.

NITROGEN FIXATION BY THE ADDITION OF LARGE AMOUNTS OF MOLASSES TO SOIL IN FIELDS

In my last Address I had the honour of submitting to you our results obtained in the fixation of atmospheric nitrogen on the addition of molasses varying from 3600 to 10800 kilograms per acre. Using 3 tons of molasses per acre 112 lbs of nitrogen fixation was observed in field trials and similarly using 10 tons of molasses per acre 270 lbs. of nitrogen are fixed. Our experiments have been continued with the addition of larger amounts of molasses and the results are recorded below:

TABLE I.

21600 kg. (20 tons) of molasses added per acre of land on 10-1-36.

| NH ₃ -N. | Nitric-N. | Available-N. | Total-N. | Total-C. |
|---------------------|-----------|--------------|----------|-----------------|
| 0·00466% | 0·00328% | 0·00794% | 0·0561% | 0·628% original |
| 0·0064 | 0·00376 | 0·01016 | 0·0636 | 2·550 10-1-36. |
| 0·00764 | 0·00286 | 0·01040 | 0·0748 | 2·060 17-2-36. |
| 0·0077 | 0·00376 | 0·01146 | 0·0758 | 1·921 3-3-36. |
| 0·00768 | 0·0037 | 0·01138 | 0·0759 | 1·912 13-3-36. |
| 0·00875 | 0·00264 | 0·01139 | 0·0781 | 1·852 4-4-36. |
| 0·00876 | 0·00364 | 0·0124 | 0·0782 | 1·844 25-4-36. |
| 0·00268 | 0·00412 | 0·0068 | 0·0603 | 1·012 17-7-36. |

TABLE 2.

42200 kg. (40 tons) of molasses added per acre of land. on 10-1-36.

| | | | | | |
|----------|----------|----------|---------|--------|-----------|
| 0·00466% | 0·00328% | 0·00794% | 0·0561% | 0·628% | Original. |
| 0·00524 | 0·0036 | 0·00884 | 0·0667 | 3·528 | 10-1-36. |
| 0·00668 | 0·00356 | 0·01024 | 0·0778 | 3·1026 | 17-2-36. |
| 0·00684 | 0·00356 | 0·01040 | 0·07822 | 2·652 | 3-3-36. |
| 0·00622 | 0·0036 | 0·00982 | 0·0783 | 2·582 | 13-3-36. |
| 0·01 | 0·00264 | 0·01264 | 0·0822 | 2·0125 | 4-4-36. |
| 0·0104 | 0·00367 | 0·01407 | 0·0831 | 1·8721 | 25-4-36. |
| 0·00312 | 0·00482 | 0·00794 | 0·070 | 1·1214 | 17-7-36. |

The foregoing results show that there is an increase in the total nitrogen and ammonia contents when molasses is added to the soil even in large amounts. Thus applying 20 tons of molasses per acre 22 milligrams of nitrogen are added in in the first 9 inches of the soil and this is equivalent to the addition of 493 lbs. of nitrogen per acre of soil. Similarly using 40 tons 605 lbs. of nitrogen are added per acre. Moreover as molasses contains potash, phosphate and increases bacterial activity and the soil humus, moisture and available nitrogen content, molasses proves to be an excellent fertilizer for tropical soils. In all our experiments, we have observed that the soil tilth considerably improves on the application of molasses.

The marked decrease of ammoniacal nitrogen in the end in Tables 1 and 2 is due chiefly to leaching as the analysis on 17th July was carried on after heavy showers in June and July. Moreover, along with the decrease in available nitrogen there has been a decrease of total nitrogen but the fall in total nitrogen is much less than in available nitrogen. Another interesting point is that the percentage of available nitrogen (the sum of ammoniacal and nitric nitrogen) in comparison with the total nitrogen is much greater in tropical soils than in soils of temperate climates. From the results recorded in the foregoing tables it is seen that the percentage of available nitrogen just before the rains is 16 to 17 of the total nitrogen of the molassed plots, whilst after the leaching due to the rains the percentage goes down to 11. Consequently leaching affects the available nitrogen of molassed plots appreciably. Hence it is clear that the nitrogen fixed by the application of carbohydrates to soils, is easily converted into the available form, and that is why carbohydrate manuring is highly beneficial to tropical soils.

FIELD TRIALS

By the application of 3600 kgms. of molasses per acre of land which was also molassed last year and digging and watering the land once in twenty days in the months of May and June 1936, 32.3 mds. (1292 kgms.) of grains of paddy were obtained per acre as against 20.5 mds. (820 kgms.) in the control plot. In these trials AUS paddy was transplanted. The amounts of straw were as follows :—Control plot = 38 maunds (1520 kgms) per acre.

Molassed plot = 85 maunds (3400 kgms) per acre.

Hence these results confirm those obtained last year.

Recent work of Sethi, Batham and Nigam in U. P. and of Mirehandani in Behar shows that molasses not only adds nitrogen to soil by fixation and improves the crop yield with wheat, rice and sugar cane but reclaims alkali soils as well. These results are in entire confirmation of the observations of Dhar and his collaborators.

NO DECREASE OF AVAILABLE NITROGEN ON THE ADDITION OF CARBOHYDRATES, GLYCEROL ETC. TO SOIL.

It is generally believed that on the addition of carbohydrates and cellulosic materials to the soil, the available nitrogen and especially the nitrate nitrogen considerably decreases and is converted into microbial tissue. In a recent communication, Allen, Abel and Magistad (Trop. Agri, 11, 285, 1935) have shown that when soil is mixed with finely divided pine-apple trash or leaves, the nitric nitrogen falls off from 0.0018% to 0.00015%. In our experiments with molasses, starch, other carbohydrates, glycerol etc. no such reduction has been observed either in light or in dark. Our field experiments as well as those carried on in dishes show that the available nitrogen (the sum of ammoniacal and nitric nitrogen) and the total nitrogen contents of the soil are never less than the original amounts present in the soil before the addition of molasses or other carbohydrates. Our experimental results with the addition of even 100 grms. of molasses to a kilogram of soil show that there is no decrease of ammoniacal and nitric nitrogen when the mixture of soil and molasses is exposed to sunlight. As a matter of fact, even after 30 hours' exposure to sunlight spread out for 5 or 6 days there is considerable increase of ammoniacal nitrogen; the nitric nitrogen remains stationary till the exposure goes up to 150 hours spread out in 40 days. At this stage the nitric nitrogen goes on increasing. In our field trials with the addition of molasses, starch, glycerol etc. even a few days after the addition of these energy-rich materials the ammoniacal

nitrogen is appreciably increased and the available and total nitrogen contents also augment due to fixation of atmospheric nitrogen. The nitric nitrogen remains stationary. Later on the oxidation continues and the nitric nitrogen also increases from the nitrification of the ammonium salts formed. This is a very important observation which differs from the experience of workers in temperate climates.

In a private communication to the author, Sir John Russell has stated as follows :—

"The results that you have obtained with molasses are of great interest both from their possible importance to agricultural practice and, owing to the interesting contrast that they show with results obtained in temperate regions by adding to soil materials rich in carbohydrates. It seems to be necessary to distinguish between the effect of molasses in stimulating nitrogen fixation and their effect in causing the assimilation of ammoniacal and nitric nitrogen and so preventing the loss of nitrogen by leaching. These two effects probably vary greatly in their relative importance under different soil and climatic conditions."

Our results obtained with molasses, sugars, starch and glycerol when added to soil kept in dishes or to the field show that the ammoniacal nitrogen and the total nitrogen increase considerably but the nitric nitrogen remains stationary up to a certain time. Hence it is practically impossible to determine accurately how much of the ammoniacal nitrogen obtained by the fixation is converted into microbial tissue. The observations recorded in Tables 1 and 2 show that the percentage of available nitrogen in the molassed fields is fairly high and it is partially washed away by rain water. These observations showing the increase of both available and total nitrogen on carbohydrate manuring explain why it is beneficial in improving crop yield in the tropics. Moreover as there is considerable fixation of nitrogen which becomes readily available to plants, molasses manuring appears to be more useful than symbiotic nitrogen fixation.

INFLUENCE OF LIGHT ON NITROGEN FIXATION.

Nitrogen fixation and Azotobacter count on the addition of cane sugar and glucose to the soil in basins.

In order to investigate whether the fixation of atmospheric nitrogen in tropical soils is mainly a bacterial one or due also to the photochemical and

other agencies experiments were done by Dhar and Seshacharyulu by adding cane sugar and glucose to the soil in basins and exposing them to the sunlight.

1000 gms. of garden soil were mixed with 20 gms. of cane sugar or glucose and 300 c. c. of water in enamelled basins and exposed to the sunlight daily for seven hours. Some basins with the same substances were kept in a dark room in order to exclude light. In one set of the experiments 2 gms. of calcium carbonate were added. 160 c. c. of water were added twice a day to the exposed basins and 160 c.c. of water to the basins kept in the dark after every three days for maintaining an uniform moisture content. Before the commencement of the experiment estimations of nitrogen, total carbon, and Azotobacter numbers of the original soil were done. At regular intervals, the nitrogen content, total carbon, and Azotobacter counts of the exposed and dark basins were determined.

The following results were obtained :—

TABLE 3

1 kilogram of soil + 2 gms. calcium carbonate + 20 gms. cane sugar.

Exposed.

| Date | Ammoniacal nitrogen % | Total nitrogen % | Total carbon % | Number of Azotobacter in millions per 1 g.m. of dry soil | |
|-----------------------------|-----------------------------|------------------------|----------------------|--|--|
| 30-12-1935 original soil | 0.00124 | 0.0433 | 0.4677 | 12.5 | Nitric nitrogen varied from 0.0316% to 0.0036%. |
| 13-1-36 | 0.00152 | 0.0433 | ... | 8.6 | |
| 30-1-36 | 0.00215 | 0.0442 | 1.0356 | 9.3 | |
| 15-2-36 | 0.00364 | 0.0488 | 0.866 | 11.3 | |
| 29-2-36 | 0.00464 | 0.0506 | 0.713 | 18.3 | |
| 16-3-36 | 0.00552 | 0.051 | 0.673 | 18.8 | |
| 31-3-36 | 0.00483 | 0.0506 | 0.563 | 13.2 | |
| 14-4-36 | 0.00392 | 0.0506 | 0.557 | 14.6 | |

TABLE 4.

1 kilogram of soil + 20 gms. cane sugar.

Exposed.

| Date | Ammoniacal nitrogen % | Total nitrogen % | Total carbon % | Number of Azotobacter in millions per 1 gm. of dry soil | |
|-----------------------------|-----------------------|------------------|----------------|---|---|
| 30-12-1935 original soil | 0·00124 | 0·0433 | 0·4677 | 12·5 | Nitric nitrogen varied from 0·003168% to 0·0036%. |
| 13-1-36 | 0·00143 | 0·0433 | ... | 6·0 | |
| 30-1-36 | 0·00205 | 0·0442 | 1·0401 | 7·9 | |
| 15-2-36 | 0·0035 | 0·0482 | 0·866 | 10·3 | |
| 29-2-36 | 0·00436 | 0·05 | 0·718 | 19·2 | |
| 16-3-36 | 0·00524 | 0·0506 | 0·602 | 18·2 | |
| 31-3-36 | 0·00476 | 0·05 | 0·552 | 17·1 | |
| 14-4-36 | 0·0038 | 0·05 | 0·549 | 16·2 | |

TABLE 5.

1 kilogram of soil + 2 gms. calcium carbonate + 20 gms. cane sugar.

Dark.

| Date | Ammoniacal nitrogen % | Total nitrogen % | Total carbon % | Number of Azotobacter in millions per 1 gm. of dry soil | |
|-----------------------------|-----------------------|------------------|----------------|---|---|
| 30-12-1935 original soil | 0·00124 | 0·0433 | 0·4677 | 12·5 | Nitric nitrogen varied from 0·003168% to 0·0036%. |
| 13-1-36 | 0·00126 | 0·0433 | ... | 9·5 | |
| 30-1-36 | 0·0015 | 0·0433 | 1·1383 | 33·7 | |
| 15-2-36 | 0·00215 | 0·0456 | 1·028 | 175·0 | |
| 29-2-36 | 0·00288 | 0·0472 | 0·928 | 250·0 | |
| 16-3-36 | 0·0032 | 0·0472 | 0·887 | 375·0 | |
| 31-3-36 | 0·00372 | 0·0488 | 0·696 | 415·0 | |
| 14-4-36 | 0·0036 | 0·0488 | 0·618 | 395·0 | |

TABLE 6.
1 kilogram of soil + 20 gms. cane sugar.

Dark.

| Date | Ammoniacal nitrogen % | Total nitrogen % | Total carbon % | Number of Azotobacter in millions per 1 gm. of dry soil | |
|-----------------------------|--------------------------|---------------------|-------------------|---|-----------------------------|
| 30-12-1935 original soil | 0·00124 | 0·0433 | 0·4677 | 12·5 | Nitric nitrogen varied from |
| 13-1-36 | 0·00125 | 0·0433 | ... | 7·4 | 0·003168% to |
| 30-1-36 | 0·00152 | 0·0433 | 1·1494 | 28·8 | 0·00325%. |
| 15-2-36 | 0·0021 | 0·0456 | 1·028 | 170·0 | |
| 29-2-36 | 0·00288 | 0·0472 | 0·922 | 245·0 | |
| 16-3-36 | 0·00336 | 0·0472 | 0·832 | 364·0 | |
| 31-3-36 | 0·0038 | 0·0488 | 0·698 | 420·0 | |
| 14-4-36 | 0·00372 | 0·0488 | 0·614 | 400·0 | |

TABLE 7
1 kilogram of soil + 2 gms. calcium carbonate + 20 gms. glucose.
Exposed.

| Date | Ammoniacal nitrogen % | Total nitrogen % | Total carbon % | Number of Azotobacter in millions per 1 gm. of dry soil | |
|---------------------------|--------------------------|---------------------|-------------------|---|-----------------------------|
| 4-2-1936 original soil | 0·00123 | 0·0433 | 0·4677 | 11·2 | Nitric nitrogen varied from |
| 22-2-36 | 0·00168 | 0·0433 | 1·1734 | 10·2 | 0·003168% to |
| 7-3-36 | 0·0028 | 0·046 | 1·0014 | 18·8 | 0·00382%. |
| 21-3-36 | 0·00348 | 0·0488 | 0·836 | 17·3 | |
| 7-4-36 | 0·0044 | 0·05 | 0·691 | 15·4 | |
| 21-4-36 | 0·00372 | 0·05 | 0·638 | 15·8 | |
| 7-5-36 | 0·00336 | 0·0488 | 0·586 | 15·1 | |
| 21-5-36 | 0·0032 | 0·0488 | 0·526 | 15·6 | |
| 7-6-36 | 0·00305 | 0·0488 | 0·518 | 15·0 | |

TABLE 8.
1 kilogram of soil + 20 gms. glucose
Exposed

| Date | Ammoniacal nitrogen % | Total nitrogen % | Total carbon % | Number of Azotobacter in millions per 1 gm. of dry soil | |
|---------------|-----------------------|------------------|----------------|---|-----------------------------|
| 4-2-1936 | | | | | |
| original soil | 0.00123 | 0.0433 | 0.4677 | 11.2 | Nitric nitrogen varied from |
| 22-2-36 | 0.00166 | 0.0433 | 1.1778 | 9.9 | 0.003168% to |
| 7-3-36 | 0.0028 | 0.0456 | 1.0014 | 17.4 | |
| 21-3-36 | 0.00336 | 0.0477 | 0.842 | 16.3 | 0.0039%. |
| 7-4-36 | 0.00452 | 0.05 | 0.694 | 16.8 | |
| 21-4-36 | 0.00388 | 0.05 | 0.642 | 16.1 | |
| 7-5-36 | 0.00343 | 0.0488 | 0.591 | 16.2 | |
| 21-5-36 | 0.00336 | 0.0488 | 0.526 | 16.1 | |
| 7-6-36 | 0.00303 | 0.0488 | 0.518 | 16.5 | |

TABLE 9.
1 kilogram of soil + 2 gms. calcium carbonate + 20gms. glucose.
Dark.

| Date | Ammoniacal nitrogen % | Total nitrogen % | Total carbon % | Number of Azotobacter in millions per 1 gm. of dry soil. | |
|---------------|-----------------------|------------------|----------------|--|-----------------------------|
| 4-2-1936 | | | | | |
| original soil | 0.00123 | 0.0433 | 0.4677 | 11.2 | Nitric nitrogen varied from |
| 22-2-36 | 0.00142 | 0.0433 | 1.2056 | 18.5 | 0.003168 % to |
| 7-3-36 | 0.00168 | 0.0433 | 1.1232 | 36.5 | 0.00328 %. |
| 21-3-36 | 0.00204 | 0.0456 | 1.0221 | 168.0 | |
| 7-4-36 | 0.00258 | 0.0466 | 0.906 | 232.0 | |
| 21-4-36 | 0.0029 | 0.0466 | 0.8074 | 315.0 | |
| 7-5-36 | 0.00329 | 0.0472 | 0.6748 | 390.0 | |
| 21-5-36 | 0.003 | 0.0472 | 0.6127 | 365.0 | |
| 7-6-36 | 0.0029 | 0.0472 | 0.5636 | 325.0 | |

TABLE 10.

1 kilogram of soil + 20 gms. glucose.

Dark.

| Date | Ammoniacal nitrogen % | Total nitrogen % | Total carbon % | Number of Azotobacter in millions per 1 gm. of dry soil. | |
|---------------------------|-----------------------|------------------|----------------|--|-----------------------------|
| 4-2-1936 original soil | 0.00123 | 0.0433 | 0.4677 | 11.2 | Nitric nitrogen varied from |
| 22-2-36 | 0.0014 | 0.0433 | 1.2016 | 18.0 | 0.003168 % to |
| 7-3-36 | 0.00164 | 0.0433 | 1.1224 | 37.5 | |
| 21-3-36 | 0.0021 | 0.0456 | 1.021 | 170.0 | 0.00328 %. |
| 7-4-36 | 0.00254 | 0.0466 | 0.908 | 22.0 | |
| 21-4-36 | 0.0028 | 0.0466 | 0.8078 | 320.0 | |
| 7-5-36 | 0.00323 | 0.0472 | 0.6662 | 395.0 | |
| 21-5-36 | 0.00305 | 0.0472 | 0.6088 | 350.0 | |
| 7-6-36 | 0.00294 | 0.0466 | 0.5546 | 345.0 | |

The above results show that although the Azotobacter numbers in the basins exposed to sunlight for 7 hours daily are much less, the amount of ammonia and total nitrogen are greater than in those kept in the dark. Moreover, the amount of carbon in the exposed basins are less than in those kept in dark. Hence in presence of sunlight the oxidation of substances like canesugar and glucose is greatly facilitated and causes the fixation of nitrogen in greater amounts than in the dark. It is clear, therefore, that in the presence of light the photochemical oxidation of energy-rich substances can cause nitrogen fixation just as the bacterial agency does under ordinary conditions. Therefore, along with bacterial fixation of nitrogen in tropical soils there is considerable fixation due to the photochemical oxidation of energy rich substances and that is why although the number of Azotobacter in the basins receiving sunlight is much less than in the basins kept in the dark, the ammonia and total nitrogen contents are greater than in the dark ones.

It may be argued that when the basins are exposed to the light the temperature of the soil is increased and this leads to an increased activity of Azotobacter and hence an increase in the nitrogen fixation. The temperature of the basins receiving sunlight varied from 40° - 44° whereas the dark room temperature varied from 25° - 30° . In a previous paper, Dhar and Tandon (*National Academy of Science, India*, 1936, 6, 35) have reported that the optimum temperature for Azotobacter is 35° and the fixation at 45° is practically the same as at 20° . Hence the nitrogen fixation due to Azotobacter alone should be practically identical in the basins kept in the dark room or receiving sunlight. In order to test this point further 200 gms. of the garden soil mixed with 2 gms. of glucose and 32 c. c. of water were incubated at 32° - 33° . Exactly another was exposed to sunlight.

The temperature of the exposed basin varied from 42° - 44° . To the exposed one 32 c. c. of water were added twice a day and to the incubated one 32 c.c. after every five days in order to keep the moisture content the same. Both the soils were analysed simultaneously on the following dates recorded in the table.

TABLE 11.

Exposed to sunlight.

| Date | Ammoniacal nitrogen | Total nitrogen | Total carbon | Number of Azotobacter in millions per 1 gm. of dry soil |
|--------------------------|---------------------|----------------|--------------|---|
| 10-3-36 original soil | 0.00108 | 0.042 | 0.441 | 7.2 |
| 1-4-36 | 0.0024 | 0.0446 | 0.619 | 12.5 |
| 11-4-36 | 0.00304 | 0.0456 | 0.511 | 15.7 |
| | | Incubated. | | |
| 1-4-36 | 0.00186 | 0.0437 | 0.684 | 31.8 |
| 11-4-36 | 0.00214 | 0.0442 | 0.602 | 45.0 |

The above results show that although the soil is incubated at 32° - 33° , which is very near the optimum for Azotobacter yet the ammonia and total nitrogen contents of the one incubated are less than that exposed, whose temperature while receiving sunlight is 42° - 44° . It appears, therefore, that the greater nitrogen fixation in presence of light is chiefly due to the photo-oxidation of the energy-rich compounds.

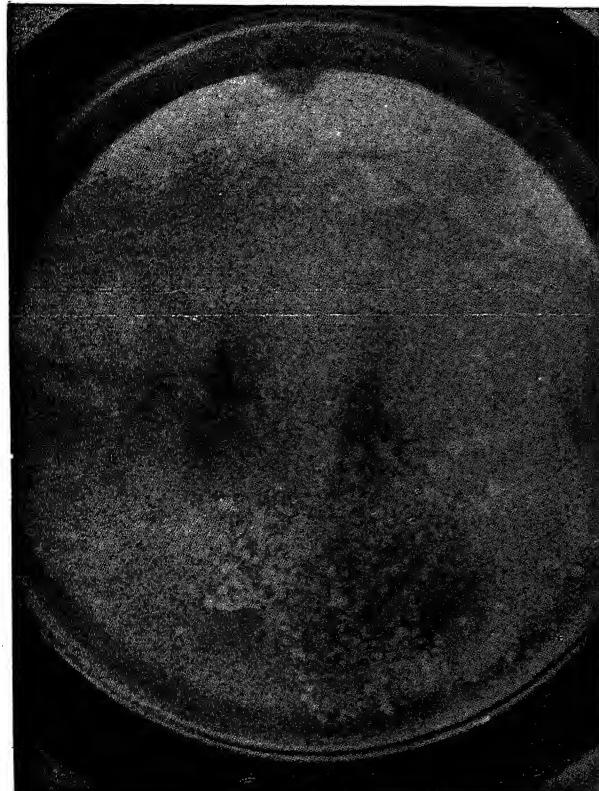
The size of the colonies developed on the plates containing the incubated soil is much bigger than those obtained from the exposed one. In the soils kept in the dark the colonies are also appreciably bigger than the colonies obtained from the soils receiving sunlight. It appears, therefore, that the Azotobacter receiving sunlight is weakened. (Vide plate I containing Azotobacter colonies from the exposed soil and plate II from the dark one.) If bacterial metabolic activity is considered to go hand in hand with the growth activity, the fixation of atmospheric nitrogen in the incubated and dark basins should have been more than the ones exposed, if no other agent was responsible in nitrogen fixation. Therefore in tropical soils along with bacterial fixation photochemical fixation seems to play a prominent rôle.

An interesting point can be deduced from our observations that the fixation is not much affected by the presence of calcium carbonate. This behaviour is due to the fact that soils with which we carried on our experiments are rich in calcium.

AZOTOBACTER COUNTS ON THE ADDITION OF STARCH, OTHER CARBOHYDRATES, GLYCEROL ETC. TO SOIL.

Similar experiments are in progress with starch, glycerol, mannitol, and mixture of molasses and soil in heaps. In the case of the starch, sugars were detected both in the exposed and dark basins. The following results were obtained,

Azotobacter Colonies in the soil
exposed to Sunlight



Azotobacter Colonies in the
soil kept in the dark

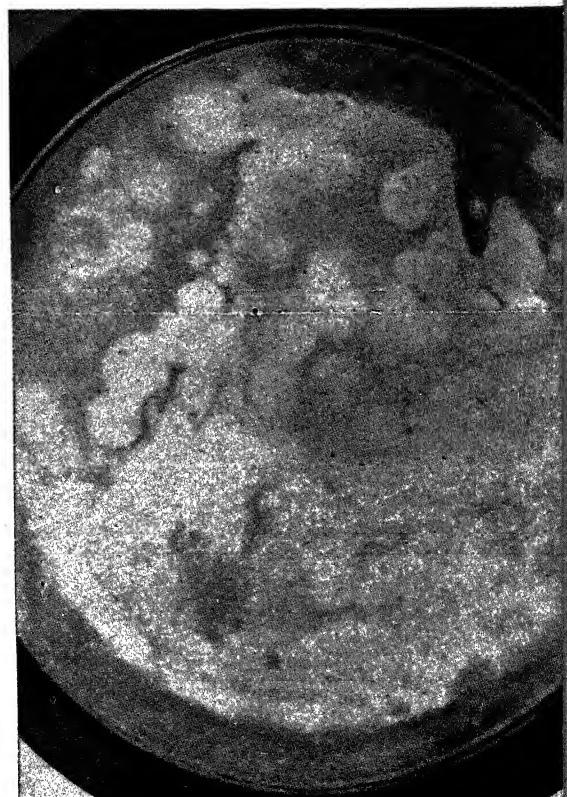


TABLE 12.

1 kilogram of soil + 50 gms. starch.

Exposed. (Temp. 36°—48°).

| Date | Ammoniacal nitrogen % | Total nitrogen % | Total carbon % | Number of Azotobacter in millions per 1 gm. of dry soil. | |
|----------------------------|-----------------------|------------------|----------------|--|-------------------------------------|
| 10-3-1936 original soil | 0.00108 | 0.042 | 0.441 | 7.2 | Nitric nitrogen varied from 0.0024% |
| 9-4-36 | 0.00109 | 0.042 | — | 6.8 | |
| 30-4-36 | 0.00184 | 0.0433 | 2.4425 | 8.2 | 0.00262 % |
| 20-5-36 | 0.00232 | 0.0442 | 2.37 | 9.1 | |
| 20-6-36 | 0.00294 | 0.0451 | 2.2765 | 15.6 | |
| 16-7-36 | 0.00336 | 0.0461 | 2.1753 | 19.8 | |
| 28-7-36 | 0.00372 | 0.0472 | 2.0932 | 28.2 | |
| 7-10-36 | 0.0052 | 0.051 | 1.411 | 38.6 | |
| 7-11-36 | 0.0056 | 0.053 | 1.2592 | 31.2 | |
| 7-12-36 | 0.0058 | 0.0538 | 1.0181 | 39.4 | |

TABLE 13.

1 kilogram of soil + 50 gms. starch.

Dark. (Temp. 28°—38°.)

| Date | Ammoniacal nitrogen % | Total nitrogen % | Total carbon % | Number of Azotobacter in millions per 1 gm. of dry soil. | |
|--------------------------|-----------------------|------------------|----------------|--|--------------------------------------|
| 10-3-36 original soil | 0.00108 | 0.042 | 0.441 | 7.2 | Nitric nitrogen 0.0024 % is constant |
| 6-4-36 | 0.00108 | 0.042 | ... | 8.1 | |
| 30-4-36 | 0.0014 | 0.042 | 2.5182 | 11.2 | |
| 20-5-36 | 0.00152 | 0.042 | 2.4761 | 18.5 | |
| 20-6-36 | 0.00184 | 0.0433 | 2.4137 | 26.8 | |
| 16-7-36 | 0.0021 | 0.0437 | 2.3352 | 46.0 | |
| 28-7-36 | 0.00232 | 0.0442 | 2.2654 | 98.6 | |
| 7-10-36 | 0.0031 | 0.0461 | 1.8286 | 205.5 | |
| 7-11-36 | 0.0032 | 0.0461 | 1.7164 | 265.5 | |
| 3-12-36 | 0.00329 | 0.0466 | 1.5382 | 305.6 | |

TABLE 14.

1 kilogram of soil + 50 gms. glycerol.

Dark. (Temp. 36°—48°.)

| Date | Ammoniacal nitrogen % | Total nitrogen % | Total carbon % | Number of Azotobacter in millions per 1 gm. of dry soil. | |
|----------------------------|-----------------------|------------------|----------------|--|-----------------------------|
| 10-3-1936 original soil | 0.00108 | 0.042 | 0.441 | 7.2 | Nitric nitrogen varied from |
| 7-4-36 | 0.00168 | 0.042 | 2.2726 | 9.1 | 0.0024 % |
| 3-5-36 | 0.00232 | 0.0442 | 2.1737 | 9.7 | 0.00258 % |
| 29-5-36 | 0.00294 | 0.0451 | 2.0314 | 12.5 | |
| 18-6-36 | 0.0034 | 0.0451 | 1.9188 | 21.5 | |
| 16-7-36 | 0.00364 | 0.0456 | 1.8123 | 27.0 | |
| 29-7-36 | 0.00388 | 0.0461 | 1.7311 | 30.8 | |
| 7-10-36 | 0.00464 | 0.0482 | 1.2685 | 36.2 | |
| 3-11-36 | 0.00508 | 0.05 | 1.0952 | 32.1 | |
| 3-12-36 | 0.00528 | 0.0507 | 0.8814 | 41.4 | |

TABLE 15.

1 kilogram of soil + 50 gms. glycerol.

Dark. (Temp. 28°—38°)

| Date | Ammoniacal nitrogen % | Total nitrogen % | Total carbon % | Number of Azotobacter in millions per 1 gm. of dry soil. | |
|----------------------------|-----------------------|------------------|----------------|--|--------------------------|
| 10-3-1936 original soil | 0.00108 | 0.042 | 0.441 | 7.2 | Nitric nitrogen 0.0024 % |
| 7-4-36 | 0.00134 | 0.042 | 2.3354 | 12.2 | is constant. |
| 3-5-36 | 0.00176 | 0.0428 | 2.2670 | 22.7 | |
| 29-5-36 | 0.00208 | 0.0437 | 2.1838 | 68.0 | |
| 18-6-36 | 0.00232 | 0.0437 | 2.1066 | 86.0 | |
| 16-7-36 | 0.00258 | 0.0437 | 2.0164 | 98.5 | |
| 29-7-36 | 0.00264 | 0.0442 | 1.9582 | 128.6 | |
| 7-10-36 | 0.003 | 0.0451 | 1.6544 | 215.0 | |
| 3-11-36 | 0.0031 | 0.0451 | 1.5612 | 286.0 | |
| 3-12-36 | 0.0032 | 0.0456 | 1.4176 | 315.0 | |

TABLE 16.

1 kilogram of soil + 20 gms. dextrin.

Exposed. (Temp. 34°—38°.)

| Date | Ammoniacal nitrogen % | Total nitrogen % | Total carbon % | Number of Azotobacter in millions per 1 gm. of dry soil. | |
|---------------|-----------------------------|------------------------|----------------------|--|---|
| 8-10-1936 | | | | | |
| original soil | 0·00145 | 0·057 | 0·6156 | 5·2 | Nitric nitrogen varied from 0·0032 % to 0·00305 %. |
| 28-10-36 | 0·00152 | 0·057 | 1·3564 | 6·1 | |
| 17-11-36 | 0·0021 | 0·059 | 1·2772 | 12·6 | |
| 10-12-36 | 0·0028 | 0·0608 | 1·1926 | 17·2 | |

TABLE 17.

1 kilogram of soil + 20 gms. dextrin.

Dark. (Temp. 28°—30°.)

| Date | Ammoniacal nitrogen % | Total nitrogen % | Total carbon % | Number of Azotobacter in millions per 1 gm. of dry soil. | |
|---------------|-----------------------------|------------------------|----------------------|--|---|
| 8-10-1936 | | | | | |
| original soil | 0·00145 | 0·057 | 0·6156 | 5·2 | Nitric nitrogen varied from 0·0032 % to 0·00305 %. |
| 28-10-36 | 0·00145 | 0·057 | 1·3892 | 4·8 | |
| 17-11-36 | 0·0016 | 0·057 | 1·3258 | 18·7 | |
| 10-12-36 | 0·00188 | 0·0586 | 1·2644 | 32·5 | |

TABLE 18.

1 kilogram of soil + 20 gms. maltose.

Exposed. (Temp. 34°-38°.)

| Date | Ammoniacal nitrogen % | Total nitrogen % | Total carbon % | Number of Azotobacter in millions per 1 gm. of dry soil. | |
|----------------------------|-----------------------|------------------|----------------|--|---------------------------------------|
| 8-10-1936 original soil | 0.00145 | 0.057 | 0.6156 | 5.2 | Nitric nitrogen 0.0032 % is constant. |
| 26-10-36 | 0.0016 | 0.057 | 1.3684 | 4.6 | |
| 12-11-36 | 0.00215 | 0.059 | 1.2672 | 16.2 | |
| 1-12-36 | 0.0027 | 0.0604 | 1.1694 | 21.5 | |
| 17-12-36 | 0.00322 | 0.0618 | 1.0712 | 32.8 | |

TABLE 19

1 kilogram of soil + 20 gms. maltose.

Dark. (Temp. 28°-30°.)

| Date | Ammoniacal nitrogen % | Total nitrogen % | Total carbon % | Number of Azotobacter in millions per 1 gm. of dry soil | |
|----------------------------|-----------------------|------------------|----------------|---|---|
| 8-10-1936 original soil | 0.00145 | 0.057 | 0.6156 | 5.2 | Nitric nitrogen varied from 0.0032% to 0.00305% |
| 26-10-36 | 0.00148 | 0.057 | 1.3944 | 4.95 | |
| 12-11-36 | 0.00168 | 0.057 | 1.3163 | 21.2 | |
| 1-12-36 | 0.0019 | 0.0586 | 1.2451 | 40.5 | |
| 17-12-36 | 0.0021 | 0.0596 | 1.1699 | 76.5 | |

TABLE 20.

1 kilogram of soil + 20 gms. fructose.

Exposed. (Temp. 34°—38°.)

| Date | Ammoniacal nitrogen % | Total nitrogen % | Total carbon % | Number of Azotobacter in millions per 1 gm. of dry soil | |
|---------------|-----------------------------|------------------------|----------------------|---|-----------|
| 8-10-36 | | | | | |
| original soil | 0.00145 | 0.057 | 0.6156 | 5.2 | Nitric |
| 25-10-36 | 0.00168 | 0.057 | 1.3568 | 6.1 | nitrogen. |
| 11-11-36 | 0.0021 | 0.0586 | 1.2622 | 13.2 | 0.0032 is |
| 1-12-36 | 0.0028 | 0.0608 | 1.1518 | 19.8 | constant |
| 17-12-36 | 0.00336 | 0.0622 | 1.0264 | 36.0 | |

TABLE 21.

1 kilogram of soil + 20 gms. fructose.

Dark. (Tem. 28°—30°).

| Date | Ammoniacal nitrogen % | Total nitrogen % | Total carbon % | Number of Azotobacter in millions per 1 gm. of dry soil | |
|---------------|-----------------------------|------------------------|----------------------|---|-----------------|
| 8-10-36 | | | | | |
| original soil | 0.00145 | 0.057 | 0.6156 | 5.2 | Nitric nitrogen |
| 27-10-36 | 0.00152 | 0.057 | 1.3745 | 7.2 | varied from |
| 11-11-36 | 0.00168 | 0.057 | 1.3161 | 19.8 | 0.0032 % to |
| 1-12-36 | 0.00186 | 0.059 | 1.2429 | 35.8 | 0.00294 % |
| 17-12-36 | 0.00215 | 0.06 | 1.1633 | 82.5 | |

TABLE 22.

1 kilogram of soil + 20 gms. galactose.

Exposed. (Temp. 34°—38°)

| Date | Ammoniacal nitrogen % | Total nitrogen % | Total carbon % | Number of Azotobacter in millions per 1 gm. of dry soil | |
|-----------------------------|-----------------------|------------------|----------------|---|-------------------------------------|
| 19-10-1936 original soil | 0.00145 | 0.057 | 0.6156 | 5.6 | Nitric nitrogen 0.0032% is constant |
| 10-11-36 | 0.00176 | 0.057 | 1.3432 | 9.2 | |
| 26-11-36 | 0.00224 | 0.06 | 1.2386 | 17.8 | |
| 10-12-36 | 0.00289 | 0.0613 | 1.1128 | 19.2 | |

TABLE 23.

1 kilogram of soil + 20 gms. galactose.

Dark. (Temp: 28°—30°).

| Date | Ammoniacal nitrogen % | Total nitrogen % | Total carbon % | Number of Azotobacter in millions per 1 gm. of dry soil | |
|-----------------------------|-----------------------|------------------|----------------|---|---|
| 19-10-1936 original soil | 0.00145 | 0.057 | 0.6156 | 5.6 | Nitric nitrogen varied from 0.0032 % to 0.00305 % |
| 10-11-36 | 0.00152 | 0.057 | 1.3618 | 13.6 | |
| 26-11-36 | 0.00172 | 0.057 | 1.2904 | 26.8 | |
| 10-12-36 | 0.0019 | 0.059 | 1.2092 | 38.6 | |

TABLE 24.

1 kilogram of soil + 20 gms. mannitol.

Exposed. (Temp. 38°—48°).

| Date | Ammoniacal nitrogen % | Total nitrogen % | Total carbon % | Number of Azotobacter in millions per 1 gm. of dry soil | |
|----------------------------|-----------------------------|------------------------|----------------------|---|-----------------|
| 20-4-1936 original soil | 0.00152 | 0.043 | 0.494 | 6.5 | Nitric nitrogen |
| 5-5-36 | 0.002 | 0.043 | 1.2087 | 11.8 | varied from |
| 22-5-36 | 0.0028 | 0.0454 | 1.0725 | 16.6 | 0.00308% to |
| 8-6-36 | 0.0035 | 0.0472 | 0.9539 | 20.5 | 0.00358%. |
| 24-6-36 | 0.00436 | 0.0489 | 0.8118 | 28.5 | |
| 14-7-36 | 0.005 | 0.0506 | 0.7156 | 32.5 | |
| 26-7-36 | 0.00536 | 0.051 | 0.6432 | 29.8 | |
| 10-8-36 | 0.0052 | 0.051 | 0.5846 | 30.5 | |
| 10-10-36 | 0.00424 | 0.0507 | 0.5124 | 18.6 | |

TABLE 25.

1 kilogram of soil + 20 gms. mannitol.

Dark. (Temp. 30°—38°).

| Date | Ammoniacal nitrogen % | Total nitrogen % | Total carbon % | Number of Azotobacter in millions per 1 gm. of of dry soil | |
|----------------------------|-----------------------------|------------------------|----------------------|--|-----------------|
| 20-4-1936 original soil | 0.00152 | 0.043 | 0.494 | 6.5 | Nitric nitrogen |
| 5-5-36 | 0.00174 | 0.043 | 1.2266 | 17.5 | varied from |
| 22-5-36 | 0.00207 | 0.043 | 1.1654 | 29.2 | 0.00308% to |
| 8-6-36 | 0.00252 | 0.0454 | 1.0912 | 110.0 | 0.0032%. |
| 24-6-36 | 0.00294 | 0.0454 | 1.0091 | 175.0 | |
| 14-7-36 | 0.00341 | 0.0466 | 0.9299 | 235.0 | |
| 26-7-36 | 0.00368 | 0.0472 | 0.8516 | 292.6 | |
| 10-8-36 | 0.00384 | 0.0477 | 0.7634 | 355.8 | |

FIELD EXPERIMENTS WITH MOLASSES.

In order to find out whether the above conclusion, namely, photochemical fixation of atmospheric nitrogen in tropical soils holds good in fields the following experiments were also performed in fields :—

Six plots of equal area ($6' \times 4'$) were taken. To one set of 2 plots 10 kilograms of molasses were added and to another set of 2 plots 5 kilograms were added. The remaining 2 plots were kept as control. One plot from each set was covered with wooden planks on raised bricks in order to exclude sunlight and the other plots were exposed to sunlight. The exposed plots were watered after every 4 days and dug up and covered plots were watered once a week but dug up simultaneously with the exposed plots. At regular intervals the Azotobacter count and nitrogen estimations of all the plots were carried on. The temperature of the exposed plots during the months of April, May and June varied from 59.5° to 38° at depths varying from 1 to 6 inches and that of the covered plots from 41° to 31.5° at the same depths.

The following results were obtained :—

TABLE 26.

Plot ($6' \times 4'$) containing 5 kilograms of molasses.

Exposed.

| Date | Ammoniacal nitrogen % | Total nitrogen % | Total carbon % | Number of Azotobacter in millions per 1 gm. of dry soil. | |
|---------------|--------------------------|---------------------|-------------------|--|-----------------|
| 14-4-36 | 0.00175 | 0.0874 | 0.7858 | 2.5 | Nitric nitrogen |
| Original soil | | | | | of the plot |
| 20-4-36 | 0.00244 | 0.0874 | 1.2054 | 10.5 | varied from |
| 03-5-36 | 0.00328 | 0.09 | 1.1326 | 32.0 | 0.00311% to |
| 21-5-36 | 0.00388 | 0.092 | 1.0474 | 40.5 | |
| 31-5-36 | 0.00432 | 0.0932 | 1.0021 | 48.5 | |
| 16-6-36 | 0.00444 | 0.094 | 0.9693 | 42.0 | |
| 17-7-36 | 0.00464 | 0.094 | 0.9562 | 49.5 | |
| 15-10-36 | 0.00319 | 0.0932 | 0.9411 | 30.5 | |

TABLE 27.

Covered

| Date | Ammoniacal nitrogen % | Total nitrogen % | Total carbon % | Number of Azotobacter in millions per 1 gm. of dry soil. |
|----------------------------|-----------------------------|------------------------|----------------------|--|
| 14-4-1936 original soil | 0.002 | 0.094 | 0.8648 | 1.9 |
| 27-4-36 | 0.00233 | 0.094 | 1.217 | 21.2 |
| 9-5-36 | 0.0028 | 0.094 | 1.2552 | 45.0 |
| 21-5-36 | 0.00308 | 0.096 | 1.2331 | 55.0 |
| 31-5-36 | 0.00328 | 0.0978 | 1.1945 | 62.0 |
| 16-6-36 | 0.00368 | 0.0978 | 1.1847 | 90.0 |
| 17-7-36 | 0.00388 | 0.0978 | 1.0504 | 115.0 |
| 15-10-36 | 0.00292 | 0.096 | 0.9824 | 56.2 |

Plot (6' x 4') containing 10 kilograms of molasses

Exposed

| Date | Ammoniacal nitrogen % | Total nitrogen % | Total carbon % | Number of Azotobacter in millions per 1 gm. of dry soil. | Notes |
|----------------------------|-----------------------|------------------|----------------|--|--|
| 11-4-1936 original soil | 0.00236 | 0.08 | 0.7332 | 2.1 | Nitric nitrogen of the plot varied from 0.0035% to 0.00352%. |
| 23-4-36 | 0.0028 | 0.08 | 1.5964 | 4.3 | |
| 6-5-36 | 0.00348 | 0.0922 | 1.4642 | 23.5 | |
| 17-5-36 | 0.004 | 0.0832 | 1.389 | 32.5 | |
| 28-5-36 | 0.00432 | 0.0848 | 1.327 | 40.0 | |
| 15-6-36 | 0.005 | 0.0862 | 1.246 | 72.5 | |
| 16-7-36 | 0.0056 | 0.0978 | 1.1216 | 88.5 | |
| 4-8-36 | 0.004 | 0.0864 | 1.0014 | 8.2 | |
| 18-10-36 | 0.00308 | 0.0864 | 0.9624 | 50.2 | After heavy rains. |

TABLE 29.
Plot (6' × 4') containning 10 kilogram of molasses.
Covered.

| Date | Ammoniacal nitrogen % | Total nitrogen % | Total carbon % | Number of Azotobacter in millions per 1 gm. of dry soil | |
|----------------------------|-----------------------|------------------|----------------|---|--|
| 11-4-1936 original soil | 0.00208 | 0.0932 | 0.9207 | 2.6 | Nitric nitrogen of the plot 0.0035% is constant. |
| 28-4-36 | 0.00236 | 0.0942 | 1.7419 | 5.8 | |
| 6-5-36 | 0.00274 | 0.094 | 1.6919 | 34.5 | |
| 17-5-36 | 0.00294 | 0.094 | 1.6334 | 43.0 | |
| 28-5-36 | 0.00308 | 0.0958 | 1.5872 | 50.5 | |
| 15-6-36 | 0.0034 | 0.0964 | 1.5234 | 86.0 | |
| 16-7-36 | 0.00388 | 0.0964 | 1.4236 | 135.0 | |
| 4-8-36 | 0.00308 | 0.0958 | 1.2036 | 88.0 | |
| 18-10-36 | 0.00274 | 0.094 | 0.9824 | 62.0 | After heavy rains. |

TABLE 30.

Control plot (6' × 4').

Exposed.

| Date | Ammoniacal nitrogen % | Total nitrogen % | Total carbon % | Number of Azotobacter in millions per 1 gm. of dry soil. | |
|-----------|-----------------------|------------------|----------------|--|-----------------------------|
| 16-4-1936 | 0.00175 | 0.1 | 0.903 | 2.4 | Nitric nitrogen of the plot |
| 28-4-36 | 0.00175 | 0.1 | 0.903 | 2.6 | varied from |
| 11-5-36 | 0.00175 | 0.1 | 0.903 | 1.6 | 0.00328% to |
| 22-5-36 | 0.00175 | 0.1 | 0.903 | 1.7 | 0.00333%. |
| 1-6-36 | 0.00169 | 0.0986 | 0.903 | 1.8 | |
| 16-6-36 | 0.00169 | 0.0986 | 0.903 | 2.1 | |
| 18-7-36 | 0.00169 | 0.0986 | 0.903 | 2.9 | |
| 20-10-36 | 0.00169 | 0.0926 | 0.903 | 2.7 | |

TABLE 31.

Control plot (6' × 4').

Covered.

| Date | Ammoniacal nitrogen % | Total nitrogen % | Total carbon % | Number of Azotobacter in millions per 1 gm. of dry soil. | |
|-----------|-----------------------------|------------------------|----------------------|--|--|
| 16-4-1936 | 0.00184 | 0.0902 | 0.8344 | 2.03 | Nitric nitrogen of the plot 0.00328% is constant. |
| 28-4-36 | 0.00184 | 0.0902 | 0.8344 | 2.8 | |
| 11-5-36 | 0.00184 | 0.0902 | 0.8344 | 2.4 | |
| 22-5-36 | 0.00184 | 0.0902 | 0.8344 | 2.3 | |
| 1-6-36 | 0.00184 | 0.0902 | 0.8344 | 2.6 | |
| 16-6-36 | 0.001804 | 0.0876 | 0.8344 | 2.9 | |
| 18-7-36 | 0.001804 | 0.0876 | 0.8344 | 3.0 | |
| 20-10-36 | 0.001804 | 0.0876 | 0.8344 | 3.1 | |

FIELD EXPERIMENTS WITH GLYCEROL AND STARCH.

TABLE 32.

Plot 4' × 4' containing 2 kilograms of glycerol.

| Date | Ammoniacal nitrogen % | Total nitrogen % | Total carbon % | Number of Azotobacter in millions per 1 gm. of dry soil. | |
|---------------|-----------------------------|------------------------|----------------------|--|--|
| 12-10-1936 | | | | | |
| original soil | 0.0009 | 0.042 | 0.4603 | 1.95 | Nitric nitrogen 0.002 % is constant. |
| 30-10-36 | 0.0012 | 0.042 | 0.7973 | 2.8 | |
| 18-11-36 | 0.00186 | 0.0437 | 0.7317 | 9.5 | |
| 5-12-36 | 0.0021 | 0.0451 | 0.6702 | 20.6 | |
| 25-12-36 | 0.0028 | 0.0466 | 0.5878 | 23.5 | |

TABLE 33.

Plot 4' x 4' containing 2 kilograms of starch.

| Date | Ammoniacal nitrogen % | Total nitrogen % | Total carbon % | Number of Azotobacter in millions per 1 gm. of dry soil. | |
|-----------------------------|-----------------------------|------------------------|----------------------|--|--|
| 12-10-1936 original soil | 0.00087 | 0.0466 | 0.5033 | 2.2 | |
| 30-10-36 | 0.00124 | 0.0466 | 0.9213 | 3.1 | |
| 18-11-36 | 0.00174 | 0.0482 | 0.8731 | 8.8 | |
| 5-12-36 | 0.002 | 0.05 | 0.8205 | 19.8 | |
| 25-12-36 | 0.00268 | 0.0512 | 0.7442 | 20.5 | |

TABLE 34.

Control plot 4' x 4'.

| Date | Ammoniacal nitrogen % | Total nitrogen % | Total carbon % | Number of Azotobacter in millions per 1 gm. of dry soil. | |
|------------|-----------------------------|------------------------|----------------------|--|--|
| 12-10-1936 | 0.00116 | 0.054 | 0.567 | 2.47 | |
| 30-10-36 | 0.00116 | 0.054 | 0.567 | 2.52 | |
| 18-11-36 | 0.00116 | 0.054 | 0.567 | 2.01 | |
| 5-12-36 | 0.00116 | 0.054 | 0.567 | 2.92 | |
| 25-12-36 | 0.00116 | 0.054 | 0.567 | 2.22 | |

The foregoing results clearly substantiate the conclusion that in tropical soils along with bacterial fixation, photochemical fixation of atmospheric nitrogen is prominent.

The results summarised in the following table show that the nitrogen fixation per gram of carbon oxidised is always much greater when the systems receive sunlight than in those kept in the dark. As a matter of fact, in many cases, the nitrogen fixation in light is practically double of that obtained in the dark. Hence it can be concluded that the nitrogen fixation in soils mixed with energy-rich materials is approximately 50 % bacterial and 50 % photochemical, consequently in sunlight nitrogen fixation is more efficient than in the dark. It seems that in nitrogen fixation in soils, which is an endothermic reaction, sunlight is utilised, as in the carbon assimilation by plants, which is also an endothermal reaction. In our experiments in the nitrogen fixation when molasses is added to alkaline soils, where the oxidation of the carbonaceous substances is quicker than in normal soils, the nitrogen fixation per gram of the energy material oxidized is much greater in light than in the dark. In several cases, the nitrogen fixation in sunlight is four times that in the dark.

TABLE 35.

Nitrogen fixed per gram of carbon oxidised.
Experiments in dishes.

| | | |
|--------------------------------|-----------|-----------|
| Cane sugar + CaCO ₃ | (Exposed) | 15·8 mgm. |
| Cane sugar | (Exposed) | 14·7 ,, |
| Cane sugar + CaCO ₃ | (Dark) | 10·5 ,, |
| Cane sugar | (Dark) | 10·2 ,, |
| Glucose + CaCO ₃ | (Exposed) | 12·5 ,, |
| Glucose | (Exposed) | 12·5 ,, |
| Glucose + CaCO ₃ | (Dark) | 6·5 ,, |
| Glucose | (Dark) | 6·5 ,, |
| Mannitol | (Exposed) | 12·8 ,, |
| Mannitol | (Dark) | 6·9 ,, |
| Starch | (Exposed) | 8·2 ,, |
| Starch | (Dark) | 4·7 ,, |
| Glycerol | (Exposed) | 6·2 ,, |
| Glycerol | (Dark) | 3·9 ,, |

Field Trials.

Plot 6' x 4' containing :—

| | | |
|-------------------------|-----------|------------|
| 5 kg. of molasses | (Exposed) | 22.9 mgm. |
| | (Dark) | 13.2 mgm. |
| Plot 6' x 4' containing | (Exposed) | 17.8 mgm. |
| 10 kg. of molasses | (Dark) | 10.06 mgm. |

NITROGEN FIXATION WITH CELLULOSIC MATERIALS. LEAVES,
COW-DUNG, ETC.

The following lines from Waksman's "Soil Microbiology" (1927) show that the problem of the fixation of nitrogen in fields supplied with cellulosic materials has not yet been satisfactory investigated.

"The importance of this process in increasing the supply of soil nitrogen is, however, still questionable." (Page 448)

"It has been found that polysaccharids, like celluloses can also serve as valuable sources of energy if they are first partially broken down by cellulose-decomposing organisms. However these results need still further confirmation." (Pages 561—62)

"Certainly the field results of A. Koch do not speak of any nitrogen fixation in the soil, following the addition of celluloses and even straw." (Page 588)

TABLE 35. (A)

Nitrogen fixation in soils with cellulosic substances, cow-dung, etc.

| | Amount originally present | Exposed to sunlight. | | | | | | Kept in diffused light. | | | |
|---|---------------------------------|----------------------|------------|------------|-------------|--------------|--------------|-------------------------|-----------|-------------|--------------|
| | | on 16-4-36. | on 5-5-36. | on 8-7-36. | on 11-8-36. | on 29-10-36. | on 11-12-36. | on 5-5-36. | on 8-7-36 | on 11-8-36. | on 29-10-36. |
| 500 g. soil + 25 g. Filter paper .. | .. NH ₃ -N = | 0·0015% | 0·0019% | 0·0028% | 0·0031% | 0·002 | 0·00184 | 0·0019% | 0·0023 | 0·0024 | 0·0018 |
| | .. NO ₃ -N = | 0·0029 | 0·0034 | 0·0041 | 0·0026 | 0·00264 | 0·00276 | 0·0034 | 0·0041 | 0·0025 | 0·0018 |
| | Total N = | 0·0626 | 0·0752 | 0·0875 | 0·0886 | 0·089 | 0·0864 | 0·0752 | 0·0834 | 0·0844 | 0·0856 |
| 500 g. soil + 25 g. Filter paper + 5 g. Molasses .. | .. NH ₃ -N = | 0·0015 | 0·0029 | 0·0030 | 0·0036 | 0·00234 | 0·00244 | 0·00216 | 0·0034 | 0·0035 | 0·00182 |
| | .. NO ₃ -N = | 0·0029 | 0·0034 | 0·0036 | 0·0028 | 0·00284 | 0·00288 | 0·0034 | 0·0038 | 0·0027 | 0·0018 |
| | Total N = | 0·0626 | 0·0752 | 0·100 | 0·101 | 0·112 | 0·108 | 0·0752 | 0·0934 | 0·0944 | 0·0955 |
| 500 g. soil + 100 g. Dry leaves .. | .. NH ₃ -N = | 0·00436 | 0·0043 | 0·0048 | 0·0058 | 0·00312 | 0·00284 | 0·004 | 0·0044 | 0·0046 | 0·00274 |
| | .. NO ₃ -N = | 0·0010 | 0·0062 | 0·0077 | 0·0054 | 0·0038 | 0·00388 | 0·0062 | 0·0064 | 0·0056 | 0·004 |
| | Total N = | 0·1362 | 0·175 | 0·185 | 0·200 | 0·2 | 0·2 | 0·175 | 0·175 | 0·1922 | 0·1958 |
| 500 g. soil + 100 g. Dry leaves + 5 g. Molasses .. | .. NH ₃ -N = | 0·0043 | 0·007 | 0·0048 | 0·0063 | 0·0035 | 0·00362 | 0·0045 | 0·0042 | 0·0056 | 0·00246 |
| | .. NO ₃ -N = | 0·0040 | 0·0062 | 0·0076 | 0·007 | 0·00468 | 0·00476 | 0·0062 | 0·0057 | 0·0062 | 0·00384 |
| | Total N = | 0·1362 | 0·1738 | 0·200 | 0·234 | 0·2321 | 0·228 | 0·175 | 0·188 | 0·2198 | 0·2123 |
| 500 g. soil + 100 g. Leaf juice .. | .. NH ₃ -N = | 0·0059 | 0·0058 | 0·0044 | 0·0031 | 0·00152 | 0·00136 | 0·0057 | 0·0052 | 0·0048 | 0·00124 |
| | .. NO ₃ -N = | 0·0099 | 0·0046 | 0·0054 | 0·0043 | 0·004 | 0·00372 | 0·0046 | 0·0043 | 0·0044 | 0·00374 |
| | Total N = | 0·1093 | 0·112 | 0·119 | 0·116 | 0·0875 | 0·0912 | 0·112 | 0·112 | 0·114 | 0·1084 |
| 500 g. soil + 100 g. Leaf juice + 5 g. Molasses .. | .. NH ₃ -N = | 0·0059 | 0·0067 | 0·0041 | 0·0028 | 0·00204 | 0·00224 | 0·0058 | 0·0042 | 0·0042 | 0·00112 |
| | .. NO ₃ -N = | 0·0099 | 0·0046 | 0·0037 | 0·004 | 0·004 | 0·00372 | 0·0046 | 0·0037 | 0·0042 | 0·00332 |
| | Total N = | 0·1093 | 0·112 | 0·148 | 0·152 | 0·0998 | 0·1186 | 0·112 | 0·138 | 0·142 | 0·1112 |

TABLE 35. (B)

| | Amount originally present on 27-7-36. | Exposed to sunlight 18-8-36. | Kept in diffused light 18-8-36 | Exposed to sunlight to 19-9-36. | Kept in diffused light to 19-9-36 | Exposed to sunlight to 4-11-36. | Kept in diffused light to 4-11-36 | Exposed to sunlight to 8-12-36. | Kept in diffused light to 8-12-36 |
|---|---------------------------------------|------------------------------|--------------------------------|---------------------------------|-----------------------------------|---------------------------------|-----------------------------------|---------------------------------|-----------------------------------|
| 500 g. soil + 100 g. cow-dung. | .. NH ₃ -N = | 0.004 | 0.0031 | 0.0026 | 0.0022 | 0.002 | 0.0021 | 0.0018 | 0.00168 |
| | .. NO ₃ -N = | 0.0018 | 0.0035 | 0.0035 | 0.0024 | 0.0022 | 0.0028 | 0.0026 | 0.00304 |
| | Total N = | 0.0905 | 0.100 | 0.100 | 0.1124 | 0.112 | 0.140 | 0.1324 | 0.1392 |
| | Total C = | — | 2.092 | 2.112 | 1.897 | 1.972 | 1.802 | 1.884 | 1.512 |
| 500 g. soil + 100 g. Cow-dung + 5 g. Molasses | .. NH ₃ -N = | 0.004 | 0.0028 | 0.0026 | 0.0021 | 0.0019 | 0.0018 | 0.0017 | 0.00184 |
| | .. NO ₃ -N = | 0.0018 | 0.0043 | 0.0043 | 0.0022 | 0.0021 | 0.0026 | 0.0025 | 0.00276 |
| | Total N = | 0.0905 | 0.100 | 0.100 | 0.1124 | 0.112 | 0.1386 | 0.1348 | 0.1386 |
| | Total C = | — | 2.152 | 2.148 | 2.00 | 2.00 | 1.924 | 1.938 | 1.672 |
| 500 g. soil + 100 g. sawdust | .. NH ₃ -N = | 0.0058 | 0.0017 | 0.0018 | 0.0016 | 0.0016 | 0.001 | 0.0008 | 0.00104 |
| | .. NO ₃ -N = | 0.0021 | 0.0026 | 0.0023 | 0.0018 | 0.0018 | 0.0019 | 0.0019 | 0.00188 |
| | Total N = | 0.083 | 0.087 | 0.0822 | 0.0881 | 0.0881 | 0.0881 | 0.0882 | 0.0881 |
| | Total C = | — | 4.573 | 4.582 | 4.321 | 4.388 | 4.286 | 4.302 | 4.1924 |
| 500 g. soil + 100 g. Sawdust + 5 g. Molasses | .. NH ₃ -N = | 0.0058 | 0.0014 | 0.0019 | 0.0012 | 0.0013 | 0.0014 | 0.0008 | 0.00136 |
| | .. NO ₃ -N = | 0.0021 | 0.0025 | 0.0022 | 0.0018 | 0.0013 | 0.0018 | 0.0019 | 0.00184 |
| | .. Total N = | 0.083 | 0.0875 | 0.0875 | 0.0881 | 0.0881 | 0.0888 | 0.0882 | 0.0888 |
| | Total C = | — | 4.582 | 4.582 | 4.334 | 4.349 | 4.294 | 4.313 | 4.202 |

Field trials with cow-dung.

Analysis
just after mixing on 18-9-36.
Analysis on 16-10-36.
Analysis on 16-11-36.
Analysis 7-12-36.

| | | | | |
|---------------------------------------|-----------------------------|--------|--------|---------|
| 25 tons of cow-dung per acre of soil. | NH ₃ -N = 0.0018 | 0.0025 | 0.0023 | 0.00128 |
| | NO ₃ -N = 0.0018 | 0.0016 | 0.0018 | 0.0035 |
| | Total N = 0.052 | 0.0608 | 0.061 | 0.0594 |
| | Total C = 0.837 | 0.807 | 0.642 | 0.638 |

| | | | | |
|--|-----------------------------|--------|--------|---------|
| 25 tons of cow-dung + 2.5 tons of molasses per acre of soil. | NH ₃ -N = 0.0018 | 0.0023 | 0.0025 | 0.00164 |
| | NO ₃ -N = 0.0018 | 0.0015 | 0.0017 | 0.00372 |
| | Total N = 0.058 | 0.070 | 0.070 | 0.0692 |
| | Total C = 0.0921 | 0.9 | 0.659 | 0.672 |

The foregoing results show that the cellulosic substances like filter paper, dry leaf, etc., when mixed with soil and exposed to sunlight or kept in the dark or diffused light cause nitrogen fixation. When mixed with small amounts of molasses the cellulosic substances undergo oxidation more readily and cause greater fixation of atmospheric nitrogen. The nitrogen fixation in sunlight is greater than in the diffused light or in the dark. Similar results have been obtained with cow-dung and wood fibre. These results are most important, because they show that cellulosic materials, plant residues, leaves, cow-dung, etc. not only increase the humus content of the soil, and improve the soil tilth, moisture retention capacity and act in the conservation of the soil nitrogen but these substances also add nitrogen to the tropical soil by nitrogen fixation. Hence cow-dung, which is used as a manure, has been found to supply to the soil not only the nitrogen it contains but it can also add nitrogen to the soil from the nitrogen of the air by fixation. In all our experiments the carbon has been found to decrease with time due to its oxidation. With cow-dung the carbon-nitrogen ratio attains the normal value in field trials within two months after its application.

According to Mutterlein's calculation (Mutterlein, 1913) one acre of soil in Germany receives yearly about 200 kgms. of cellulose in the form of manure. It appears that this large amount of cellulosic matter added to the soil may be partially utilised in nitrogen fixation in temperate climates. In tropical climates, due to the high temperature and great intensity of sunlight and the greater activity of the Azotobacter, the soluble carbohydrates, pentosans and cellulosic substances are oxidised at the soil surface at a great speed with the liberation of large amounts of energy necessary for nitrogen fixation. Hence manuring of tropical soils by the application of molasses and cellulosic materials is a highly important practical proposition. We are of the opinion that Indian soils would have been exhausted from the nitrogen point of view long ago had not the compensating agency, e.g. the fixation of atmospheric nitrogen by the addition of carbohydrates, pentosans and cellulosic materials to the soil been counteracting the nitrogen loss. Moreover the researches of Dhar and Atma Ram (1933) show that the tropical soil receives more available nitrogen from rain water than in temperate climates.

Russell ('Soil Conditions and Plant Growth, 1931, page 362) has reported that the nitrogen content of a grass land increased from 0·152% in 1856 to 0·338% in 1912. Similarly a land permanently covered with vegetation for 24 years showed an increase from 0·108% to 0·145%. It appears that this

increase in the total nitrogen content of these soils is chiefly due to the fixation of nitrogen from air caused by the liberation of energy from the oxidation of cellulosic and other carbonaceous substances on the surface of the soil.

INFLUENCE OF SUNLIGHT ON THE NITROGEN FIXATION BY COW-DUNG IN FIELDS.

34 tons of fresh cow-dung added per acre.

| | NH ₃ -N | NO ₃ -N | Total-N | Total-C | Analysed on |
|---------------|--------------------|--------------------|---------|---------|-------------|
| Uncovered | 0.00181% | 0.00192% | 0.0636% | 0.8801% | 20-11-36 |
| Covered with | | | | | |
| Wooden planks | 0.00152 | 0.00187 | 0.0584 | 0.8453 | , |
| Uncovered | 0.00187 | 0.00192 | 0.0736 | 0.7114 | 23-12-36 |
| Covered | 0.00104 | 0.00186 | 0.0584 | 0.785 | , |

48 tons of fresh cow-dung added per acre.

| | | | | | |
|-----------|---------|--------|--------|--------|----------|
| Uncovered | 0.00175 | 0.0025 | 0.0692 | 0.8618 | 20-11-36 |
| Covered | 0.00176 | 0.0026 | 0.070 | 0.8692 | , |
| Uncovered | 0.00177 | 0.0026 | 0.076 | 0.6921 | 23-12-36 |
| Covered | 0.00133 | 0.0026 | 0.0728 | 0.7214 | , |

68 tons of fresh cow-dung added per acre.

| | | | | | |
|-----------|---------|--------|--------|--------|----------|
| Uncovered | 0.00187 | 0.0018 | 0.0744 | 0.9703 | 20-11-36 |
| Covered | 0.0025 | 0.0031 | 0.0875 | 1.672 | , |
| Uncovered | 0.0020 | 0.0018 | 0.0823 | 0.8471 | 23-12-36 |
| Covered | 0.0017 | 0.0029 | 0.0875 | 1.013 | , |

The foregoing results show that with cow-dung applied to field, there is marked nitrogen fixation in sunlight even in 33 days but in the covered plots, there is little or no nitrogen fixation. These results are of great importance proving the enhancement of nitrogen fixation by sunlight in the oxidation of cellulose, pentosan etc. present in cow-dung and the efficiency of the nitrogen fixation in sunlight is greater than in the dark. Sunlight appears to be utilised in the process of nitrogen fixation in the soil.

The following lines from "Nature" 183, 649 (1936) are of interest in this connection.

PROMOTION OF NITROGEN FIXATION IN TROPICAL SOILS.

At intervals since the beginning of the present century studies have been made of the value of molasses as a soil improver and a number of investigators have examined the possibility that the action of the molasses was, partly an indirect one, that of increasing nitrogen fixation. As there has been a certain conflict of results particularly on the practical side, there is room for further investigation of the problem, and the contributions of Prof. N. R. Dhar and his co-workers at the University of Allahabad are to be welcomed. They have already shown considerable nitrogen fixation under tropical conditions when energy-rich materials such as soluble carbohydrates or molasses are added to the soil. They are now attacking the general problem of increasing soil nitrogen by supplying the nitrogen fixing organisms with sources of energy, and in a communication to the editor dated August 18, 1936, Prof. Dhar and Mr. S. K. Mukerji report appreciable gains in nitrogen content when soils to which filter paper, dried leaves or leaf juice had been added, were kept under laboratory conditions for several months. There were still greater increases in nitrogen content when molasses was also added, while soils exposed to sunlight for 6 hours daily gained slightly more than those kept in the dark. Sodium salts of organic acids, namely sodium citrate, stearate, palmitate and oleate, exposed to light under similar conditions gave smaller but consistent increases in soil nitrogen. From one-half to two-thirds of the added carbon was oxidised at the same time. The authors point out that since molasses and cellulosic materials not only increase the humus content of the soil and improve its physical conditions but also promote nitrogen fixation, the manuring of tropical soils with such substances should be a highly important practical proposition."

It appears that there is a fundamental difference in the mechanism of fixation of atmospheric nitrogen by carbohydrates and cellulosic substances, because the available nitrogen (sum of ammoniacal and nitric nitrogen) is always greater throughout the whole time in the process of nitrogen fixation with carbohydrates, glycerol etc. On the other hand, with cellulosic materials in the beginning the available nitrogen is always less than that originally present in the soil. It seems that a part of the available nitrogen is formed into proteins either as microbial tissue or as

ordinary amino acids. Later on the protein nitrogen is made available to the plant by the oxidation of the amino acids or the microbial tissues.

The comparatively quick oxidation of the carbohydrates on the soil surface liberates energy more readily than in the case of the celluloses because the oxidation of the latter group of substances is slower than that of the carbohydrates. The ease with which energy required for nitrogen fixation whether due to light or to bacteria is available on the soil surface, seems to determine the nature of the products of nitrogen fixation to be first detected.

NITROGEN FIXATION BY THE OXIDATION OF FATS AND SODIUM SALTS OF FATTY ACIDS.

It is generally believed that fats are oxidised in the soil with great difficulty. According to Rubner (Arch. Hyg. 91, 290, 1922.), when 4·5 gms. of fats are added to 200 gms. of soil only 38·1% undergo decomposition in 12 years. Our experience is, however, different as will be evident from the following tables.

TABLE 36.

1 kilogram of soil + 20 gms. butter.

Exposed. (Temp. 34°-38°).

| Date | Ammoniacal nitrogen % | Total nitrogen % | Total carbon % | Number of Azotobacter in millions per 1 gm. of dry soil. | |
|-----------------------------|-----------------------------|------------------------|----------------------|--|--|
| 13-10-1936 original soil | 0·00145 | 0·057 | 0·6156 | 5·1 | Nitric nitrogen 0·0032% is constant. |
| 14-11-36 | 0·0015 | 0·057 | 1·4195 | 5·7 | |
| 15-12-36 | 0·0016 | 0·057 | 1·3883 | 7·6 | |

TABLE 37.

1 kilogram of soil + 20 gms. butter.

Dark. (Temp. 28°-30°).

| Date | Ammoniacal nitrogen % | Total nitrogen % | Total carbon % | Number of Azotobacter in millions per 1 gm. of dry soil | |
|-----------------------------|-----------------------------|------------------------|----------------------|---|--------------------------------|
| 13-10-1936 original soil | 0.00145 | 0.057 | 0.6156 | 5.1 | Nitric nitrogen varied from |
| 14-11-36 | 0.00148 | 0.057 | 1.4564 | 6.6 | 0.0032 % to |
| 15-12-36 | 0.00152 | 0.057 | 1.4278 | 8.5 | 0.00305 % . |

TABLE 38.

Plot 4' × 4' containing 2½ kilograms of butter.

| Date | Ammoniacal nitrogen % | Total nitrogen % | Total carbon % | Number of Azotobacter in millions per 1 gm. of dry soil | |
|----------------------------|-----------------------------|------------------------|----------------------|---|--------------------------------|
| 6-11-1936 original soil | 0.00152 | 0.0442 | 0.4729 | 1.2 | Nitric nitrogen 0.0022 % is |
| 7-12-36 | 0.00186 | 0.0442 | 1.2276 | 4.5 | constant. |
| 4-1-37 | 0.0021 | 0.0446 | 1.194 | 7.8 | |

TABLE 39.

Plot 4' x 4' containing 2 kilograms of ghee.

| Date | Ammoniacal nitrogen % medium Azotobacter | Total nitrogen % medium Azotobacter | Total carbon % medium Azotobacter | Number of Azotobacter in millions per 1 gmt. of dry soil. |
|----------------------------|--|---|---|---|
| 7-11-1936 original soil | 0.0012 | 0.0166 | 0.5033 | 1.12 |
| 7-12-36 | 0.0011 | 0.0166 | 1.2276 | 3.75 |
| 4-1-37 | 0.00186 | 0.0471 | 1.1718 | 8.5 |

TABLE 40.

Nitrogen fixation in the oxidation of sodium salts of organic acids.

| | NH ₃ -N. | Nitric-N. | Total-N. | Total-C. | Heat of combustion of the acid per 1 gm. |
|---|---------------------|---------------------|----------|----------|--|
| | | Analysed on 14-4-36 | | | |
| Sodium tartrate | | | | | |
| 12.924 g. + 200 g. soil | 0.00186 | 0.00164 | 0.0458 | 2.268 | |
| Sodium citrate 12.22 g. + 200 g. soil | 0.00186 | 0.00164 | 0.0458 | 2.424 | |
| Sodium stearate 10.8 g. + 200 g. soil | 0.00186 | 0.00164 | 0.0458 | 4.384 | |
| Sodium palmitate 107g. + 200 g. soil | 0.00186 | 0.00164 | 0.0458 | 3.887 | |
| Sodium oleate 10.86 g. + 20 g. soil | 0.00186 | 0.00164 | 0.0462 | 4.02 | |
| | | Analysed on 16-7-36 | | | |
| Sodium tartrate 12.924 g. + 200 g. soil | 0.0014 | 0.00144 | 0.0467 | 1.872 | 1.88 Cal. |
| Sodium citrate 12.22 g. + 200 g. soil | 0.0014 | 0.00144 | 0.05 | 1.91 | 2.48 Cal. |
| Sodium stearate 10.8 g. + 200 g. soil | 0.00116 | 0.00194 | 0.0583 | 2.323 | ... |
| Sodium palmitate 10.7 g. + 200 g. soil | 0.0019 | 0.00268 | 0.054 | 2.212 | 9.21 Cal. |
| Sodium oleate 10.86 g. + 22 g. soil | 0.0014 | 0.0025 | 0.0534 | 2.4522 | ... |

In the oxidation of fats energy is liberated and this is utilized in the fixation of atmospheric nitrogen. From the foregoing results it will be seen that the greater the energy liberation from the oxidation of sodium salts of fatty acids, the greater is the amount of nitrogen fixation. Thus with sodium stearate, palmitate and oleate, there is more nitrogen fixation than with the sodium salts of the other acids. Moreover, in the oxidation of glycerol which is a component part of all fats, nitrogen fixation is also observed. It appears, therefore, that in the oxidation of all energy-rich materials on the soil surface nitrogen fixation is a general phenomenon.

COMPOSTING OF PLANT RESIDUES LESS BENEFICIAL UNDER
TROPICAL CONDITIONS THAN THEIR APPLICATION DIRECT
TO THE SOIL.

Straw, leaves and other plant residues have been utilised in the preparation of artificial farm-yard manure or compost from times immemorial. The scientific study and application of this problem was initiated by Hutchinson and Richards at Rothamsted (1921) and elaborated by different investigators notably at Indore by Howard and Wad (1931), Jackson, Wad and Panse (1934), Brown and Smith (1929), Flieg (1930), Niklewski (1915), Murray (1921) and others. On the other hand, Albrecht and Poirot (1923), Gilbert and Pember (1933), Gerlach (1925) and others have expressed doubt regarding the value of these composts and the practicability of their preparation under temperate and tropical conditions. In many cases losses of nitrogen have been reported.

From our experiments on the fixation of nitrogen by the addition of green and dry leaves, paper, sawdust, straw etc. to the soil in fields, we are of the opinion that it is more profitable to add these plant residues direct to the soil before composting. When these plant residues are added to the soil and ploughed under before the rainy season, in three months, they are considerably decomposed and the carbon of the materials undergoes oxidation on the soil surface with the liberation of energy necessary for nitrogen fixation. These plant materials, therefore when added to the soil directly not only supply the nitrogen, potash etc. they contain but can fix appreciable amounts of nitrogen on the soil surface and enriches the soil. If the plant materials are not in large excess, they are considerably decomposed and oxidised within three months after their application and the carbon-nitrogen ratio of

the soil attains the normal value. The humus, the colloidal matter and the nitrogen contents are increased. The tilth, the moisture retention and nitrogen conservation capacity are considerably improved. In composting the aim is to conserve the total nitrogen originally present in the materials and add it to the soil along with the carbon of the compost. In our method of adding the plant materials direct to the soil not only the nitrogen present in the original material is added but considerable amounts of nitrogen increase in the soil takes place due to fixation of atmospheric nitrogen. It appears, therefore, that the application of the plant materials direct to the soil is more beneficial than composting them, because the high temperature and sunlight available in tropical countries are helpfull in the ready decomposition and oxidation of the celluloses, pentonsans, lignin etc. added with the plant material for the liberation of energy necessary for nitrogen fixation.

IS THE SOIL OF INDIA BECOMING EXHAUSTED ?

This question has been repeatedly asked but so far no satisfactory answer was forthcoming. Dr. J. A. Voelcker in his "Improvement of Indian Agriculture" 1893 p. 37 recorded the following results at Rothamsted in the case of wheat grown on fields continuously unmanured for over 40 years :

| | Crop yield in Bushels per acre |
|--------------------|-----------------------------------|
| 8 years (1844—51) | 17 |
| 20 years (1852—71) | 13·9 |
| 20 years (1872—91) | 11·1 |

These results show that there is a slow deterioration of the unmanured fields at Rothamsted. Dr. Voelcker concluded that under existing conditions of agriculture, the soil of India must become gradually poorer.

On the other hand, Howard and Wad in their "Waste Products of Agriculture" 1931, p. 38 have stated as follows :—"A good example of such a system of farming without manure is to be found on the alluvial soils of the United Provinces, where the field records of ten centuries prove that the land produces fair crops year after year without any falling off in fertility. A perfect balance has been reached between the manurial requirements of the crops harvested and the natural processes which recuperate fertility."

G. Clarke in his Presidential address to the Agriculture section of the Indian Science Congress (Proc. 17th. Indian Science Congress 1930 p. 23) has stated the position in the following words :—

“ When we examine the facts, we must put the Northern Indian cultivator down as the most economical farmer in the world as far as the utilization of the potent element of fertility—nitrogen goes. In this respect he is more skilful than his Canadian brother. He cannot take a heavy over draft of nitrogen from soil. He has only the small current account provided by the few pounds annually added by nature, yet he raises a crop of wheat on irrigated land in the United Provinces that is not far removed from the Canadian average. He does more with a little nitrogen than any farmer I ever heard of. We need not concern ourselves with soil deterioration in these Provinces. The present standard of fertility can be maintained indefinitely.”

“ In India, we have in existence at least a perfect balance between the nitrogen requirements of the crops we harvest and the processes which recuperate fertility.”

It is well known that about half of every crop—the root system remains in the ground at harvest time and thus provides the soil with cellulosic and other carbonaceous materials. From our experimental observations showing that cellulosic and other energy-rich substances when added to the soil cause marked nitrogen fixation, it can be concluded that from the oxidation of the cellulosic and other carbonaceous substances, the nitrogen fixed on the soil surface, supplies the plant need.

The results recorded in the following Table, show that the nitrogen contents of the control field and the molassed one do not decrease appreciably when paddy is cultivated on these fields. It seems, therefore, that the nitrogen need of crops in tropical countries, can be met by the nitrogen fixed from air due to the energy liberated from the oxidation of the cellulosic materials left behind in the soil after harvesting. Moreover, the available nitrogen in rain water in tropics is greater than in that of temperate countries. In cold countries, chiefly due to the inactivity of Azotobacter caused by the low temperature of the soil and lack of sunshine the cellulosic and other energy-rich materials added to the soil along with plant residues, are not oxidized as readily as in tropical soils and hence much nitrogen fixation is not possible in the soil of temperate countries. This explains the slow deterioration of the unmanured fields of Rothamsted already referred to. From the above observations, it

seems that in tropical countries, almost a constant yield of crop which is not high, in unmanured fields, is possible due to the addition of nitrogen to the soil by the fixation of atmospheric nitrogen caused by the energy produced from the oxidation of plant residues left in the soil or added to it. We have observed that cellulosic materials are oxidized to carbon dioxide by passing air through a mixture of cellulose and sterile soil or ferrous hydroxide in a silica vessel, which is exposed to sunlight.

TABLE 41.

Control Plot.

(Unmanured)

| | NH ₃ -N. | NO ₃ -N. | Total-N. | Total-C. |
|--|---------------------|---------------------|----------|----------|
| Analysis on 18-5-35 after ploughing ... | ... 0.00094% | 0.0036% | 0.0468% | 0.5349% |
| Analysis after a rice crop of 340 kilograms grain and 898 kilograms straw per acre were taken away, on 6-12-35 ... | 0.000824 | 0.00186 | 0.0437 | 0.5178 |
| Analysis on 15-1-36 ... | 0.00083 | 0.00188 | 0.0437 | 0.5178 |
| Analysis on 22-7-36 (after heavy rains) ... | 0.0012 | 0.00232 | 0.0404 | 0.4424 |
| Analysis after a rice crop of 820 kilograms grain and 1520 kilograms straw per acre were taken away on 2-11-36 ... | 0.0012 | 0.00103 | 0.0437 | 0.4324 |
| Analysis on 4-12-36 ... | 0.00144 | 0.00176 | 0.054 | 0.6452 |

4260 kilograms of molasses per acre, on 26-4-35.

| | NH ₃ -N. | NO ₃ -N. | Total-N. | Total-C. |
|--|---------------------|---------------------|----------|----------|
| Analysis after application on 18-5-35 ... | 0.00099% | 0.0036% | 0.0498% | 0.6783% |
| Analysis after a rice crop of 567 kilogram grains and 1077 kilograms straw per acre were taken away on 6-12-35 ... | 0.00108 | 0.00288 | 0.053 | 0.7221 |
| Analysis on 15-1-36 ... | 0.00112 | 0.003 | 0.0533 | 0.7125 |
| Treated with molasses at the same rate on April 1936 and analysed on 22-7-36 (after heavy rains) ... | 0.00126 | 0.0029 | 0.0523 | 0.6666 |
| Analysis after a rice crop of 1292 kilograms grain and 3400 kilograms straw per acre were taken away, on 2-11-36 ... | 0.0014 | 0.00147 | 0.0538 | 0.6456 |
| Analysis on 4-12-36 ... | 0.00144 | 0.00176 | 0.054 | 0.6452 |

In publications from these Laboratories (Compare Dhar 'Influence of light on some Biochemical Processes—Society of Biological Chemists, Bangalore, India, 1935) we have tried to establish that light plays an important rôle in the processes of ammonification, nitrification, denitrification and nitrogen fixation under aërobic conditions in the soil. From our experimental results we are convinced that all these soil processes can take place in the complete absence of micro-organisms provided light is available. It is gratifying to note that soil bacteriologists like Dr. Corbet, working at Jealott's Hill Experimental Station, England, Dr. Allen of the Hawaii University, and Messrs. Sakaria and Fazaluddin of the Agricultural College Lyallpur, Punjab and others are in general agreement with our conclusions, although some investigators were unable to confirm our observations. The main difficulty of this type of work is that in all these processes ultraviolet light being more effective than visible radiations, glass vessels are not much good as they cut off most of the ultraviolet radiations. When proper precaution is taken regarding the technique, our results ought to be easily reproducible.

Recently Wal and Aurangabadkar (1936) have obtained greater amounts of nitrate formation in sunlight than in the shade using sterile and ordinary soils in the nitrification of ammonium sulphate and composts but these authors attribute without proper evidence the greater nitrification in sunlight to higher temperature rather than to sunlight. In this connection, the following statements of Corbet (1935 ; 1934) are of considerable interest :—*'The photochemical oxidation of ammonia to nitrous acid.'* The recent investigations of Dhar and his co-workers show clearly that nitrite formation can be effected in the absence of micro-organisms. In the present research, experiments were carried out to determine the extent of the photochemical oxidation of ammonium sulphate and the results obtained by the Indian investigators were confirmed.

The criticisms advanced by Fraps and Sterges against the work of Dhar and Gopala Rao are without substance, since in their experiments, soil was exposed to the sun in pyrex beakers covered with glass. The writer has confirmed that no ultraviolet radiations of wavelength capable of oxidising ammonium salts to nitrite can penetrate these materials.

More O. N. Allen (1934) has made the following observations :—*'Photochemical nitrification'* :—The work of Rao and Dhar has done much to explain nitrification in tropical areas upon a purely chemical basis. Their results seem to warrant that to a great extent nitrification is photochemical in nature,

the process taking place at the surface of various tropical soils in the presence of certain photosensitisers under the influence of sunlight.'

TABLE 41.
Nitrification of Ammonium salts exposed to sunlight for 550 hours.

| Condition | Nature of soil | Amount of salt unoxidised | Amount of salt oxidised | Percentage oxidised |
|-----------|----------------|---|-------------------------|---------------------|
| Sunlight | unsterilised | NH_4Cl . 1.98 gm. | 2.6 gm. | 58 |
| Dark | " | 4.2 | 0.7 | 14 |
| Sunlight | sterilised | 2.3 | 2.3 | 50 |
| Dark | " | 4.4 | 0.5 | 10.2 |
| Sunlight | unsterilised | $(\text{NH}_4)_2\text{HPO}_4$. 1.85 gm. | 2.8 | 60.2 |
| Dark | " | 4.4 | 0.55 | 11.1 |
| Sunlight | sterilised | 2.15 | 2.75 | 55 |
| Dark | " | 4.6 | 0.30 | 6 |
| Sunlight | unsterilised | $(\text{NH}_4)_2\text{SO}_4$. 3.35 gm. | 1.15 | 23 |
| Dark | " | 4.75 | 0.15 | 3 |
| Sunlight | sterilised | 4.2 | 0.8 | 16 |
| Dark | " | 4.85 | 0.1 | 2 |

Influence of light on Ammonification.

In a recent communication Dhar and Atma Ram (1933) have shown that aqueous solutions of amino acids like glycine are very readily oxidised into ammonia, formaldehyde and carbon dioxide when exposed to air and light. Experiments carried on *in vitro* by Dhar and Mukerji, Gopala Rao and Dhar show that the amounts of ammonia obtained on exposing solutions of amino acids like glutamic acid, aspartic acid, etc. to light increase on passing air through solutions of these amino acids. These are cases of oxidative deamination. The formation of ammonia from these amino acids is greatly increased by the presence of the solid surfaces like TiO_2 , ZnO , SiO_2 etc., the best results are obtained with TiO_2 . The following table shows the amounts oxidized with different nitrogenous substances after 20 hours' exposure to sunlight. In the dark, there is no oxidation,

TABLE 42

| | No surface | | With 5 gms. TiO ₂ | |
|---------------|--|--|--|--|
| | Air not passed (percentage oxidised) | Air passed (percentage oxidised) | Air not passed (percentage oxidised) | Air passed (percentage oxidised) |
| Aspartic acid | 0.062 | 0.064 | 4.43 | 5.32 |
| Glutamic acid | 0.059 | 0.063 | 0.35 | 0.44 |
| Egg-yellow | 0.16 | 0.194 | 5.7 | 9.7 |
| Egg-white | 0.145 | 0.222 | 17.6 | 40. |
| Blood serum | 0.844 | 0.996 | 10.8 | 12.8 |
| Gelatin | 0.762 | 0.822 | 39.9 | 45.1 |

TABLE 43.

The following results show that proteins are more easily oxidised than the amino acids :

| | Percentage oxidation after 20 hours' exposure with TiO ₂ | Amount of total nitrogen in grams as NH ₃ per litre |
|---------------|---|--|
| Glutamic acid | 0.34 | 0.570 |
| Aspartic acid | 4.45 | 0.640 |
| Gelatin | 39.9 | 2.377 |
| Blood serum | 10.8 | 4.715 |
| Egg-white | 17.6 | 3.180 |
| Egg-yellow | 5.7 | 3.505 |

These experimental results show that on exposing ammonium salts to light mixed with soil, the greater part of the ammonium compound is oxidised to nitrite and nitrate after 550 hours' exposure with ammonium phosphate and chloride. The sulphate is much less oxidised. The oxidation in vessels coated with black Japan enamel (dark) is much smaller than those receiving light. If nitrification is mainly a bacterial process as is generally believed, the amount of nitrification in the vessels in the dark with unsterilised soil should not have been materially different from those exposed to light. Moreover, the nitrification in the vessels kept in the dark and containing unsterile soil is not widely different from those with the sterile soil. It seems likely that due to the high temperature also prevailing in the dark vessels, the bacteria considerably decrease in numbers. As the light and dark experiments are exactly comparable, any bacterial contamination due to the introduction of air containing dust particles should affect the nitrification in all sets equally, because the experiments are conducted in the same place. The results of our experiments, however, show that nitrification is only prominent in vessels receiving sunlight and this is not likely to be a matter of chance only. Exactly similar behaviour is observed in our experiments on ammonification.

In a recent quantitative study, we have been able to show that dilute solutions of sodium or potassium nitrite are almost completely oxidised to nitrate when exposed to light along with photocatalysts like TiO_2 , ZnO , Fe_2O_3 and sterilised soil in the absence of bacteria. In the following table the results obtained with ZnO as the photocatalyst are summarized :—

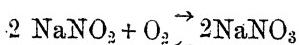
TABLE 44.

Photo-oxidation of nitrite to nitrate.

Amount of nitrite-nitrogen and total N in gm./100 c.c. after an exposure of—

| Original amount to start with | 20 hours | | 40 hours | | 60 hours | | 80 hours | | |
|----------------------------------|--------------------|---------|----------------------------|--------------------|----------|----------------------------|--------------------|---------|---------|
| NO ₂ -N Total N | NO ₂ -N | Total N | NO ₂ -N Total N | NO ₂ -N | Total N | NO ₂ -N Total N | NO ₂ -N | Total N | |
| 0.0686 | 0.0686 | 0.0648 | 0.0684 | 0.06304 | 0.0684 | 0.050 | 0.0684 | 0.0432 | 0.0684 |
| 0.0343 | 0.0343 | 0.0280 | 0.03452 | 0.0234 | 0.03398 | 0.01522 | 0.03396 | 0.00761 | 0.0341 |
| 0.0171 | 0.0171 | 0.00934 | 0.01346 | 0.003226 | 0.01599 | 0.00006 | 0.01598 | nil | 0.0162 |
| 0.00855 | 0.00855 | 0.00108 | 0.00848 | nil | 0.00848 | nil | 0.00848 | nil | 0.00848 |

The foregoing results show that in the more concentrated solutions the amount of oxidation is less, but in the dilute solutions even after 40 hours' exposure the oxidation of the sodium nitrite to sodium nitrate is complete. It is clear, therefore, that aqueous solutions of a nitrite when exposed to light and air undergo the following reversible change:—



Thus from the experimental work carried on in these laboratories we find that not only are ammonium salts oxidised to nitrite by air in the presence of light but the nitrites are also in their turn, readily converted into nitrate when exposed to light and air along with the photocatalyst. It seems, therefore, that the whole processes of nitrification and nitrogen-fixation may be photochemical.

The increase in the fertility of soil as a result of exposure to sunlight as practised in India, Egypt and other countries from time immemorial can be easily explained from our photochemical theory.

Influence of temperature on bacterial nitrification.

The bacterial theory of nitrification and of other soil processes has been holding the field to a large extent. However, there are certain facts known to us which do not find a solution on the bacterial theory. Our attention was, therefore, directed to find out the cause of these divergencies and various experiments were conducted in these laboratories.

We made a study of the effects of temperature on nitrite formers and Azotobacter in pure cultures. Bacterial decomposition of urea was also studied by us. We further investigated the oxidation of nitrites to nitrates in sunlight in presence of photocatalysts like ZnO , TiO_2 , Fe_2O_3 soil, etc. We shall briefly summarise our results and the conclusions arrived at.

Influence of temperature on bacterial nitrification.

For the study of nitrite formers a pure culture of nitrite forming bacteria was prepared from the garden soil by Omeliansky's method of elective culture, the medium employed being :—

| | | | | |
|---------------------|-----|-----|-----|--|
| Ammonium Sulphate | ... | ... | ... | 2 to 2.5 gm. |
| Potassium Phosphate | ... | ... | ... | 1 " |
| Magnesium Sulphate | ... | ... | ... | 0.5 " |
| Sodium Chloride | ... | ... | ... | 2 " |
| Ferrous Sulphate | ... | ... | ... | 0.4 " |
| Distilled Water | ... | ... | ... | 100 c.c. |
| Magnesium Carbonate | ... | ... | ... | Excess (0.5 gm. per 50 c. c. of the medium) |

Equal portions of the medium containing a known amount of the culture were taken in conical Jena-glass flasks and were kept at various temperatures. The amount of nitrite formed was estimated by a Duboscq colorimeter from time to time using a mixture of 0.8 per cent. solution of sulphanilic acid in acetic acid of specific gravity 1.04 and 0.5 per cent. solution of naphthylamine in acetic acid of the same specific gravity as the indicator. The results are recorded below :—

TABLE 45.

Amount of nitrite formed at various temperatures (Gm. of NO_2 per litre).

Nitrite formed at temperatures of

Time

0° 15° 20° 25° 30° 35° 40°

| Hours. | 0.000253 | 0.0001525 | 0.001169 | 0.005066 | 0.00792 | 0.008848 | 0.00064 |
|--------|----------|-----------|----------|----------|---------|----------|----------|
| 67 | 0.000281 | 0.0002884 | 0.00175 | 0.008505 | 0.02304 | 0.0438 | 0.000689 |
| 115 | 0.000281 | 0.0004045 | 0.002779 | 0.01777 | 0.04971 | 0.09385 | 0.000844 |
| 163 | 0.000281 | 0.0006595 | 0.002953 | 0.02656 | 0.0673 | 0.1438 | 0.000950 |
| 187 | 0.000281 | 0.001318 | 0.00376 | 0.0386 | 0.08503 | 0.1987 | 0.001076 |
| 211 | 0.000281 | 0.002163 | 0.004468 | 0.05737 | 0.1026 | 0.2715 | 0.00141 |
| 235 | 0.000281 | ... | 0.00559 | 0.08585 | 0.12595 | 0.3585 | 0.001781 |
| 259 | 0.000281 | | | | | | |

At 50° the amounts of nitrite formed in the flasks containing the bacteria were the same as in the control flasks containing no bacteria.

The results recorded in Table 45 clearly show that the optimum temperature of nitrification with the tropical nitrite forming bacteria is about 35° . On account of the high temperatures existing for the greater part of the year in the tropics the bacteria in soils of tropical countries have so adapted themselves as to thrive best at 35° . It is interesting to note that Panganiban (1925) working in the Phillipines has also observed an optimum temperature of 35° with his nitrite-forming bacteria.

Table 45 shows that at 0° the bacteria are capable of maintaining the life activity for some days but a prolonged exposure to this temperature ultimately results in the complete stoppage of their life activity. Such a culture when brought back again to optimum conditions fails to show any further sign of growth even after being kept for 9 months. At 50° also we find that the bacteria are incapable of existence.

The study of the bacterial ammonification of urea at different temperature gave the following results:—

Influence of temperature on the ammonification of urea.

TABLE 46.

Amounts in 5 c.c. of the urea solution which was equivalent to 0.0444 gm. N.

| Temperature | 31°. | 35° | 40° | 50° | 55° |
|---------------|---|--|---|---|---|
| Time in hours | NH ₃ -N am. in gms. monifi- cation % | NH ₃ -N am. in gm. monifi- cation % | NH ₃ -N am. in gms. monifi- cation % | NH ₃ -N am. in gms. monifi- cation % | NH ₃ -N am. in gms. monifi- cation % |
| 36 | 0.00195 4.39 | 0.007613 17.14 | 0.01628 36.66 | 0.00005 0.10 | 0.00004 0.09 |
| 60 | 0.01473 33.18 | 0.0225 50.7 | 0.02433 54.8 | 0.00006 0.11 | 0.00004 0.09 |
| 84 | 0.02347 52.9 | 0.0322 72.56 | 0.03246 73.1 | 0.000067 0.12 | |
| 108 | 0.02442 55.0 | 0.03466 78.1 | 0.03495 78.7 | | |
| 132 | | 0.0374 84.3 | 0.0379 85.4 | | |

The above results show that the optimum temperature for bacterial ammonification in the tropics is near about 40° . The maximum temperature for the survival of the bacteria seems to be between 50° and 55° .

Thus we see that the optimum temperature for ammonification is higher than the optimum for nitrification. This shows that ammonifying bacteria have a greater resisting capacity with respect to temperature than is the case with the nitrite-forming bacteria. A similar relationship has also been noticed by workers in colder countries though there the optima for nitrification and ammonification are much below those existing in the tropics.

Influence of temperature on nitrogen-fixation by Azotobacter.

The following procedure was adopted for the study of nitrogen-fixation by Azotobacter kept at various temperatures.

A three days old culture of Azotobacter cells was prepared and 0·2 c.c. of this was added to each flask containing forty cubic centimeters portions of the sterile mannite medium plugged with absorbent cotton. The flasks were kept at various temperatures along with the control ones and the nitrogen fixed in the form of NH₃ was estimated from time to time by Nessler's reagent in a Duboscq colorimeter. The results are recorded below :—

TABLE 47.

Gram of ammoniacal N per litre.

| Hours | At temperatures of | | | | | | | |
|-------|--------------------|----------|---------|---------|----------|----------|-----|-----|
| | 10° | 20° | 30° | 35° | 40° | 50° | 60° | 70° |
| 96 | nil | 0·00086 | 0·00105 | 0·00243 | 0·00096 | 0·000782 | nil | nil |
| 168 | " | 0·002169 | 0·00677 | 0·0161 | 0·002749 | 0·001674 | " | " |
| 216 | " | 0·00565 | 0·0116 | 0·0254 | 0·0064 | 0·00357 | " | " |
| 264 | " | 0·00862 | 0·012 | 0·0296 | 0·00924 | 0·00545 | " | " |
| 312 | " | 0·01041 | 0·015 | 0·0354 | 0·01054 | 0·00654 | " | " |
| 360 | " | 0·01352 | 0·0167 | 0·0423 | 0·01375 | 0·00895 | " | " |
| 408 | " | 0·0152 | 0·0207 | 0·0504 | 0·0153 | 0·0094 | " | " |

The foregoing results show that the maximum amount of nitrogen-fixation by Azotobacter which we isolated from our garden soil is at about 35° whilst at 10° , 60° , and 70° there is no nitrogen-fixation. The cultures at 10° and 60° were plated on solid agar medium and it was found that a few colonies developed on the plates containing the culture at 10° while on the plates containing the culture kept at 60° practically no colony appeared. This shows that although a few Azotobacter cells may remain alive at 10° their activity is practically nil, which is evident from the fact that no ammonia formation could be detected in the experimental flasks kept at the said temperature.

Investigations carried on in different temperate countries show that the optimum temperature is appreciably lower for Azotobacter in colder countries than 35° .

In the summers of 1933 and 1936 we recorded the soil temperatures at Allahabad; in the month of April it rose to 50° at 2 inches depth. May and June of 1933 were frequently cloudy and the summer was a mild one.

Leather working at Pusa, India stated that the maximum temperature at Pusa may rise to 70° at the soil surface and 60° at a depth of 1 or 2 inches. In Egypt the recorded temperature is 65° at the surface and 56° at a depth of 2 inches. From our measurements on the influence of temperature on bacterial nitrogen transformations we find that 35° is generally the optimum temperature for these processes in the tropics. Beyond 50° the bacterial effect becomes negligible. Hence in tropics, nitrification and nitrogen-fixation in soil can not be to any large extent of bacterial origin in the months of April, May, June and July in the day time when the soil temperature is much greater than the optimum for these bacteria. In these very months the nitrate in soil is, however, the greatest. Even in colder countries like England and Germany, the soil temperature may rise to 35° or more in summer although the optimum temperature for bacterial nitrification there is stated to be 25° .

In these countries also the bacterial nitrification must be greatly reduced in the summer months as a result of the soil temperature becoming greater than the optimum temperature for bacterial nitrification though the nitrate content of the soil in these countries is also largest in the summer time.

It is generally agreed that nitrification is most active at the surface of the soil. According to Prescott and Piper nearly 80% of the nitrate accumulation takes place in the first $3\frac{1}{2}$ inches of the soil from the surface. The observations recorded previously show that the soil temperature in the summer months

in tropical countries must not be much below 50° even at the depth of 3½ inches from the surface although the bacterial nitrification has the optimum temperature of 35°. It appears, therefore, that in the first 3½ inches of the soil where there is maximum nitrification as observed by different investigators, very few bacteria can exist in tropical countries in summer months, although the amount of nitrate in soil is maximum in summer. We are led to conclude, therefore, that agencies other than bacterial must be active in causing nitrification which is going on at a maximum speed in the soil in summer months within 3½ inches of the soil. As we have observed that light markedly accelerates the oxidation of amino acids to ammonia, of ammonium salts to nitrites, of nitrites to nitrates and the fixation of atmospheric nitrogen and that all these oxidations are accelerated by increase of temperature, we are led to believe that light absorption and increase of temperature play a more important rôle than bacteria in nitrogen changes in soil in summer months.

In publications from these laboratories it has been shown that the oxidation of ammonium salts mixed with sterilized or unsterilised soil in covered vessels coated with Japan black enamel when kept in the sun along with the vessels receiving light is much smaller than in those exposed to light. If nitrification were mainly a bacterial process, the amount of nitrification in the vessels in the dark with the unsterilised soil should not have been materially different from those exposed to light. We have made numerous comparative experiments like those on the oxidation of ammonium salts to nitrite and of nitrite to nitrate with both sterilised and unsterilised soil kept in light and in dark and we find that the formation of nitrite and nitrate is always much greater in the vessels exposed to light than in those kept in the dark.

From all the points discussed in the preceding sections, it seems that nitrogen transformations in soil are due more to light than to bacteria specially in tropical countries.

AVAILABLE NITROGEN IN TROPICAL SOILS.

Regarding the amounts of available nitrogen (sum of ammoniacal and nitric nitrogen) present in English soils, Russell (1932) has stated as follows:—

‘In normal conditions, the nitrate and ammonia together rarely account for more than one per cent of the nitrogen in the soil.

‘Usually the total amount of nitrogen is so large in comparison with the amount of nitrate that the changes in amount fall within the limits of experimental error.’

'Neither ammonia nor nitrate normally occurs in the soil in any great quantity; an usual range on land carrying vegetation is from 5 to 25 part of nitric nitrogen and about 5 to 10 parts of ammonia per million of soil, corresponding to about one to three per cent of the total nitrogen.'

The amount of available nitrogen in Russian soils various from 0.36 to 4.6%.

It has already been emphasised that the oxidation processes taking place in the soil are facilitated to a greater extent in tropical countries due to sunlight and higher soil temperatures than in temperate climates. It is expected, therefore, that the percentage of available nitrogen in the tropical soil is greater than in cold countries.

In order to test this point, we have determined the total, ammoniacal and nitric nitrogen of samples of soils collected from different parts of India. Our results can be summarised as follows:—

ASSAM (Nyagogra tea estate). Four samples of soils analysed; the available nitrogen varies from 25.1 to 40.4% of the total nitrogen, of which the variation is from 0.092 to 0.139% of the soil.

BENGAL (Dacca and Nadia). Six samples analysed; the available nitrogen varies from 14.3 to 29.7% of the total nitrogen, of which the variation is from 0.057 to 0.227% of the soil.

BIHAR (Pusa). Five samples collected in July, 1932 and analysed in April 1935; the available nitrogen varies from 28.1 to 47.7% of the total nitrogen, of which the variation is from 0.0238 to 0.0313% of the soil.

UNITED PROVINCES (Allahabad). (a) Thirteen samples of ordinary garden soil analysed; the available nitrogen varies from 10 to 31.6% of the total nitrogen, of which the variation is from 0.0347 0.0582% of the soil.

(b) Five samples of molassed soil of which the C : N ratio is constant, analysed; the available nitrogen varies from 11.7 to 28% of the total nitrogen, of which the variation is from 0.0437 to 0.09% of the soil.

THE PUNJAB (Ranjitkot, Hiyatpur and Chhanwali). Three samples analysed; the available nitrogen varies from 13.4 to 15.2% of the total nitrogen of which the variation is from 0.04 to 0.0582% of the soil.

MADRAS (Waltair). Two samples analysed; the available nitrogen varies from 15 to 24.9% of the total nitrogen, of which the variation is 0.0309 to 0.0625% of the soil.

The foregoing results show that the amounts of available nitrogen varies from 10 to 47.7% of the total nitrogen in the soils collected from different parts of India. The percentage of available nitrogen of a soil from Bangalore, which is a cool place is 8.5. Hence the portion of available nitrogen in comparison with the total nitrogen in tropical soils is much greater than that present in soils of temperate climates. It appears, therefore, that the solar radiations, which fall on the tropical soil, help in the oxidation of the nitrogenous substances present in the soil, which is rendered suitable for plant growth, although the total nitrogen in tropical soils is generally less than in those of temperate countries.

SIGNIFICANCE OF CARBON-NITROGEN RATIO IN SOIL.

It is well known that in soil which is well aerated the chemical changes affecting the carbon and the nitrogen present in the soil are intimately connected. It is generally believed that the combined nitrogen existing in the soil can form nitrate only if the ratio of carbon to nitrogen is not greater than 10 to 11 and when the proportion of carbon is greater, the excess is oxidised to carbon dioxide and the nitrogen remains as complex protein. When, on the other hand, the proportion of nitrogen is greater than the above ratio, the nitrogenous compound is changed into ammonia and nitrate.

From our researches on the nitrogen transformations in the soil, we are of the opinion that when the carbon content of the soil is increased by the addition of energy-rich substances like carbohydrates, cellulose, etc. the energy-rich substances are readily oxidized on the soil surface causing nitrogen fixation. This important factor tends to increase the nitrogen content of the soil. The oxidation of carbohydrates, cellulosic materials, etc. on the soil surface may take place through the agencies of bacteria, sunlight, inductors, and catalysts. Whatever may be the agency which is effective, these processes cause liberation of energy which is utilized in the nitrogen fixation. Under ordinary soil conditions, all these agencies are responsible for the oxidation of carbohydrates and cellulosic materials; and in this process the soil is enriched from the nitrogen point of view. In presence of large amounts of carbohydrates and cellulosic materials, the proteins, amino acids, ammonium salts present in soil are protected from oxidation and these are conserved in the soil. When the carbonaceous substances are oxidized to a great extent,

ammonification, nitrification, etc. which are also mainly oxidation processes accelerated by sunlight, high temperature, surface of catalysts, inductors, bacteria, etc. become prominent in the soil. In these processes appreciable amounts of loss of nitrogen in the gaseous state takes place.

The retarding influence of different carbohydrates and carbonaceous compounds in the processes of ammonification and nitrification is observed with different bacteria, fungi, etc. of different energy and food requirements and is not regulated by their demands but forms a part of an universal phenomenon taking place in the animal, plant, and in soil processes as well as *in vitro*, in which it is always observed that a readily oxidisable organic substance can act as a negative catalyst in the oxidation of another substance. We are of opinion, therefore, that the carbon-nitrogen ratio in soils is not controlled by the energy requirements of the micro-organisms, as advocated by Doryland (1916) but is regulated by the ease with which proteins, amino acids, ammonium salts, etc. are oxidised by air, aided by bacteria, catalysts and light in presence of carbonaceous substances under different conditions and the oxidations taking place in the soil seem to be guided by the same laws, which rule animal metabolism.

Influence of temperature on the carbon-nitrogen ratio in soils.

A garden soil is being heated in a steam oven at 80°-85° for nearly two years and the carbon-nitrogen ratio has been determined from time to time. The following results show that the carbon-nitrogen ratio appreciably increases as the heating is continued :—

TABLE 48.

| Date of analysis | Carbon | Nitrogen | C/N |
|------------------|--------|----------|-------|
| 23-2-35 | 0.563 | 0.056 | 10.05 |
| 23-3-35 | 0.57 | 0.0544 | 10.45 |
| 23-4-35 | 0.5608 | 0.0509 | 11.01 |
| 23-7-35 | 0.5646 | 0.045518 | 12.48 |
| 4-5-36 | 0.5581 | 0.04227 | 13.2 |

The foregoing results support our contention that the greater is the temperature of the soil, the higher is the carbon-nitrogen ratio.

Our experimental results show that the carbon-nitrogen ratio is highest in the soils from the Punjab and the value is 14.4; in the United Province

it is 11.3, in Bihar it is 9.2 and in Bengal the ratio is 9.1. The carbon-nitrogen ratio in soils collected from different countries seem to support the above view-point. The average ratio of 50 English soils is 10. In Wales it is 9.2. In the Washington State after long cultivation the value is 10.2. In Sudan it is 12.6 and in Transvaal it is 14.4.

Our results showing that the C-N ratio increases with increase of soil temperature are in agreement with those obtained by Mc. Lean (Journ. Agric. Sci. 1930, **20**, 348) but are contrary to those calculated by Jenny (Soil Sci. 1929, **27**, 168).

NITROGEN LOSS FROM SOIL IN SUNLIGHT AND ITS RETARDATION BY CARBONACEOUS SUBSTANCES.

The researches of Lipman and Blair, (*Soil Sci.*, 12, 1, 1921.) Russell and Richards, (*J. Agric. Sci.*, 8, 495, 1917), Shutt, (*ibid.*, 3, 335, 1910) and others show that nitrogen in the gaseous stage is lost from soils when the conditions are favourable for oxidation. The loss of nitrogen in this process may be more than double the amount of nitrogen taken up by the plant grown on the soil. Nearly 70% of the added nitrogen is said to have been lost when wheat plots in Rothamsted, England, have received annually 14 tons of farmyard manure containing 200 lbs. nitrogen per acre.

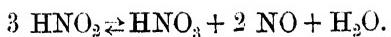
A greater loss of nitrogen is observed when a manure is composted under aerobic than anaerobic conditions. According to Niklewski (*Roczn Nauk Roln.*, 9, 1 1923.) there is more loss of nitrogen from stable manure in presence of nitrifying bacteria than in their absence. It has also been reported that in the nitrification of different oil-cakes, the loss of nitrogen is the greatest with the most easily and quickly nitrifiable cakes. Recently Viswanath, (*Sci. Reports Dept. Agric. Madras* 1930-31)) has obtained greater nitrogen loss and greater velocity of oxidation in the nitrification of ammonium salts than with farmyard or green manure. It is established that when there is a large amount of carbonaceous matter present in the manures along with nitrogenous compounds, the velocity of the oxidation of nitrogenous compounds and the amount of nitrogen loss are also decreased.

Experiments carried on at different places show that the total amount of nitrate present in soils containing crops is less than that in neighbouring fallow soils even when a correction is applied for the amount of nitrate taken up by the crop. The oxidation processes are more vigorous in soils with crops

than in those without them. Russell (*Soil Conditions and Plant Growth*, pp. 368-369, 1932) has stated this problem of the loss of nitrogen in the following words:—“There is considerable difficulty in accounting for the nitrogen lost from the soil during the first 20 or 30 years of cultivation. It has, therefore, been supposed that nitrogen is evolved during the oxidation, and as all attempts to break off nitrogen from nitrate in these conditions have failed, it is assumed to come from the organic matter. This assumption involved the difficulty that no loss of nitrogen has been observed in the straightforward bacterial oxidation of organic substances such as albumin, asparagin or mixtures such as urine or faeces.” ‘Yet somehow and somewhere gaseous nitrogen must be evolved to balance the considerable amount of fixation that is known to take place.’

The results obtained by Dhar, Tandon, and Mukerji (*J. Indian Chem. Soc.*, **12**, 67 1935) show that the loss of nitrogen on exposing ammonium salt solutions to light and air is always greater in light than in the dark. The oxidation of ammonium salts by air is greater in light than in the dark and hence the possibility of the formation of ammonium nitrite is greater in light than in the dark. Several years ago Dhar (*Proc. K. Akad. Wet. Amsterdam*, **23**, 308, 1920) observed that solutions of ammonium nitrite decompose into nitrogen and water when exposed to sunlight and this photochemical decomposition is facilitated by acids and different solid surfaces. Moreover, the recent observations of Dhar, Tandon and Mukerji (*loc cit.*) show that solutions of ammonium chloride and sodium nitrite decompose readily with evolution of nitrogen when exposed to sunlight in glass beakers or quartz tubes mixed with sterilised or unsterilised soil. This decomposition can take place under completely sterilised conditions in the complete absence of bacteria. Moreover, this decomposition is less pronounced in dilute solutions of ammonium nitrite and also when cane sugar is added to the solution containing ammonium and nitrite ions.

All these observations have been explained from the viewpoint that in the processes of ammonification and nitrification taking place in the soil or in solutions, ammonium nitrite is produced. Solutions of ammonium nitrite have been found to decompose into nitrogen and water readily by increase of temperature or exposing them to light. The formation of ammonium nitrite from ammonium salts or proteins requires oxygen and that is why, this type of denitrification is facilitated by increased soil aeration and also soil acidity, as nitrous acid also undergoes decomposition according to the equation;



This chemical change is also markedly accelerated by light.

There is also the possibility of the reaction of nitrous acid on amines amides and amino acids, which may sometimes be formed in the decomposition of soil organic substances. This important phenomenon first studied systematically by Lipman and Blair and emphasised by Russell has now been satisfactorily explained by Dhar and collaborators, *Nature*, 134, 572 (1934). That this type of nitrogen loss from soils is chiefly due to the formation and decomposition of the unstable ammonium nitrite, is supported by the fact that soil loses nitrogen in this way much less when manured with sodium or potassium nitrate than when manured with ammonium sulphate or organic nitrogenous manures. Because in the process of nitrification with the latter class of compounds, the unstable substance ammonium nitrite is formed. It has been postulated that this type of denitrification may be caused by the interaction of hyponitrous acid and hydroxylamine formed in nitrification. Unfortunately the evidence in favour of the existence of these compounds in soil appears unsatisfactory.

Addition of carbonaceous substances like molasses tends to preserve the soil nitrogenous compounds present in the soil by decreasing the probability of the formation and decomposition of ammonium nitrite.

TABLE 49.

Decomposition of ammonium nitrite solutions at 20° and 30°.

NH₃-N added as (NH₄)₂SO₄ = 0·14 g. = 10 cc. NO₂-N added as Ba(NO₃)₂ = 0·148 gr. = 0·29 gr.

Light (1000 watt tungsten filament lamp).

| Exposure at | NH ₃ -N. left. | NO ₂ -N. left. | Total-N. left. | NH ₃ -N. lost. | NO ₂ -N. lost. | Total-N. lost. | % lost. |
|------------------|------------------------------|------------------------------|-------------------|------------------------------|------------------------------|-------------------|------------|
| 30° for 5 hours | 0·1343 g. | 0·1422 g. | 0·2786 g. | 0·0057 g. | 0·0058 g. | 0·0114 g. | 3·6 |
| 30° for 10 hours | 0·1272 | 0·135 | 0·2642 | 0·0128 | 0·013 | 0·0258 | 8·2 |
| 30° for 20 hours | 0·112 | 0·12 | 0·234 | 0·028 | 0·028 | 0·056 | 19·6 |
| 20° for 5 hours | 0·14 | 0·148 | 0·29 | nil | nil | nil | nil |
| 20° for 10 hours | 0·1312 | 0·14 | 0·271 | 0·0088 | 0·0098 | 0·019 | 6·5 |
| 20° for 20 hours | 0·123 | 0·132 | 0·257 | 0·017 | 0·016 | 0·033 | 11·3 |
| 20° for 40 hours | 0·1152 | 0·1248 | 0·2402 | 0·0248 | 0·0232 | 0·0498 | 17 |

| | Dark. | | | | | |
|------------------|--------|--------|--------|--------|--------|------------|
| 30° for 5 hours | 0·14 | 0·148 | 0·29 | nil | n'l | nil nil |
| 30° for 10 hours | 0·1372 | 0·1452 | 0·2855 | 0·0028 | 0·0027 | 0·0045 0·1 |
| 30° for 20 hours | 0·1327 | 0·14 | 0·2754 | 0·0073 | 0·008 | 0·0146 5 |
| 20° for 5 hours | 0·14 | 0·148 | 0·29 | nil | nil | nil nil |
| 20° for 10 hours | 0·14 | 0·148 | 0·29 | nil | nil | nil nil |
| 20° for 20 hours | 0·14 | 0·148 | 0·29 | nil | nil | nil nil |
| 20° for 40 hours | 0·1318 | 0·14 | 0·2729 | 0·0082 | 0·008 | 0·0171 5·7 |

| | Loss of nitrogen in | | | Percentage loss in | |
|----------------|---------------------|------------|------------|--------------------|--------|
| | Dark + Light. | Dark only. | Light only | Dark. | Light. |
| 5 hrs. at 30° | 0·0114 g. | nil | 0·0114 g. | nil | 3·9 |
| 10 hrs. at 30° | 0·0258 g. | 0·0045 | 0·0213 | 0·1 | 8·1 |
| 20 hrs. at 30° | 0·056 | 0·0146 | 0·0414 | 5·0 | 14·6 |
| 5 hrs. at 20° | n'l | nil | nil | nil | nil |
| 10 hrs. at 20° | 0·019 | nil | 0·019 | 0· | 6·5 |
| 20 hrs. at 20° | 0·033 | nil | 0·033 | 0· | 11·3 |
| 40 hrs. at 20° | 0·0498 | 0·0171 | 0·0327 | 5·7 | 11·5 |

The foregoing results show that solutions of ammonium nitrite decompose appreciably in the dark at 20° and 30°. This decomposition is appreciably increased by exposing the solutions to the total light from a 1000 watt tungsten filament lamp. In sunlight this decomposition is greatly enhanced (compare Dhar and Mukerji, J. Indian Chem. Soc.)

TABLE 41.

Influence of sunlight on the nitrification and denitrification of ammonium sulphate added to fields

138·6 kg of nitrogen as $(\text{NH}_4)_2\text{SO}_4$ per acre of land used.

Condition. NH₃-N. Nitric-N. Available-N. Total-N. Total-C. Date of

| | | | | | Analysis |
|-----------|---------|---------|----------|---------|----------------|
| Uncovered | 0·032% | 0·0028% | 0·0348 % | 0·14% | 0·476% 18-1-36 |
| Covered | 0·0373 | 0·004 | 0·0413 | 0·148 | 0·48 |
| Uncovered | 0·008 | 0·00934 | 0·01734 | 0·1081 | 0·481 30-1-36 |
| Covered | 0·032 | 0·0056 | 0·0376 | 0·1382 | 0·482 |
| Uncovered | 0·00582 | 0·01132 | 0·01714 | 0·1032 | 0·478 19-2-36 |
| Covered | 0·0224 | 0·0082 | 0·0306 | 0·1328 | 0·478 |
| Uncovered | 0·00504 | 0·01194 | 0·01698 | 0·0995 | 0·478 9-3-36 |
| Covered | 0·02176 | 0·00924 | 0·031 | 0·1324 | 0·472 |
| Uncovered | 0·00416 | 0·01224 | 0·0164 | 0·0982 | 0·478 4-4-36 |
| Covered | 0·0211 | 0·00976 | 0·0308 | 0·1312 | 0·478 |
| Uncovered | 0·00324 | 0·01302 | 0·1626 | 0·09212 | 0·478 25-4-36 |
| Covered | 0·0185 | 0·01144 | 0·0299 | 0·1308 | 0·478 |

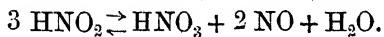
TABLE 49.

| 277·2 kg. of nitrogen as $(\text{NH}_4)_2\text{SO}_4$ per acre of land used. | | | | | | |
|--|-----------|---------|-----------|---------|-----------|---------|
| | Uncovered | Covered | Uncovered | Covered | Uncovered | Covered |
| | 0·0168% | 0·0028% | 0·0496% | 0·2000% | 0·4760% | 18-1-36 |
| | 0·0624 | 0·004 | 0·0664 | 0·2 | 0·482 | , |
| | 0·0234 | 0·01468 | 0·03803 | 0·167 | 0·481 | 30-1-36 |
| | 0·0500 | 0·0048 | 0·0548 | 0·1902 | 0·482 | , |
| | 0·020 | 0·01488 | 0·03488 | 0·1425 | 0·478 | 19-2-3 |
| | 0·0442 | 0·00844 | 0·05264 | 0·1842 | 0·478 | , |
| | 0·01844 | 0·01544 | 0·03338 | 0·1325 | 0·478 | 9-3-36 |
| | 0·0425 | 0·00936 | 0·05186 | 0·1841 | 0·478 | , |
| | 0·01784 | 0·0157 | 0·03354 | 0·1281 | 0·472 | 4-4-36 |
| | 0·04024 | 0·01056 | 0·0508 | 0·1834 | 0·478 | , |
| | 0·00862 | 0·01848 | 0·0271 | 0·1122 | 0·472 | 25-4-36 |
| | 0·03824 | 0·01242 | 0·0506 | 0·1832 | 0·472 | , |

These experimental results show definitely, that the nitrification of ammonium sulphate is much quicker in the plots receiving sunshine, than in those which are covered with wooden planks. Moreover, in the uncovered plots there is more nitrogen loss than in the covered plots. Thus when 138·6 kg. of nitrogen were added to the soil, the loss in nitrogen in the uncovered plots amounted to 34·2% in about 3 months, whereas in the covered plots the loss is only 11·6%. Similarly with 277·2 kg. of nitrogen the loss is 43·9% in the uncovered and 8·2% in the covered plot. These results conclusively prove that in presence of sunlight ammonium sulphate is nitrified at a much greater speed than in the dark. Along with the greater velocity of nitrification in sunlight, there is a concomitant greater loss of nitrogen in sunlight than in the dark. These results strongly support our conclusion, that sunlight plays an important part in the nitrification and in denitrification in tropical countries.

We have already emphasised that this type of denitrification, when the conditions are favourable for oxidation and nitrification of the nitrogenous compounds in the soil, is caused by the formation and decomposition of NH_4NO_2 in the process of nitrification. The formation of ammonium nitrite from ammonium salts and proteins, requires oxygen, and that is why this type of denitrification is facilitated by increased soil aeration. In the process of nitrification, the ammonia ion is replaced first, by the acidic NO_2^- ion and

finally by NO_3 and hence in the process of nitrification the acidity of the system increases. It is well known that nitrous acid decomposes according to the equation.



Moreover, acids have been found to facilitate the thermal and photochemical decomposition of ammonium nitrite, which is temporarily formed in the soil in the process of nitrification. Murty and Dhar (1931) have also shown that sunlight or artificial light markedly accelerates the decomposition of nitrous acid according to the above equation. All these factors are responsible for the nitrogen loss from soils, when ammonium salts or proteins added or present in the soil undergo nitrification. In previous pages it has been emphasised that the presence of carbonaceous substances like carbohydrates, fats, etc. along with the nitrogenous substances retard the nitrogen loss from soils. It has been shown by us that in presence of the carbonaceous substances, the velocity of nitrification of nitrogenous compounds is decreased and consequently the nitrogen loss is concomitantly decreased. The following field trials obtained with the addition of $(\text{NH}_4)_2\text{SO}_4$ to the soil with or without molasses show definitely that molasses retards the velocity of nitrification and denitrification in soils.

TABLE 50.

Retardation of nitrogen loss from field soils by the addition of molasses.

| Condition. | NH ₃ -N. | Nitric-N | Available. N | Total-N. | Total-C | Date of analysis. |
|------------|---------------------|----------|-----------------|----------|---------|----------------------|
| Unmolassed | 0.00832% | 0.00350% | 0.01182% | 0.0583% | 0.416% | 27-9-35 |
| Molassed | 0.00814 | 0.00350 | 0.01164 | 0.0588 | 0.587 | " |
| Unmolassed | 0.00636 | 0.00556 | 0.01192 | 0.0583 | 0.416 | 12-10-35 |
| Molassed | 0.00778 | 0.00426 | 0.01204 | 0.0609 | 0.578 | " |
| Unmolassed | 0.00608 | 0.006 | 0.01208 | 0.0538 | 0.416 | 24-10-35 |
| Molassed | 0.00778 | 0.00582 | 0.01360 | 0.0625 | 0.501 | " |
| Unmolassed | 0.00438 | 0.00714 | 0.01152 | 0.0538 | 0.411 | 7-11-35 |
| Molassed | 0.0070 | 0.00636 | 0.01336 | 0.636 | 0.498 | |

| Condition. | NH ₃ -N. | Nitric-N. | Available-N. | Total-N. | Total-C. | Date of analysis. |
|------------|---------------------|-----------|--------------|----------|----------|-------------------|
| Unmolassed | 0.0042 | 0.00714 | 0.01130 | 0.0538 | 0.412 | 13-12-35 |
| Molassed | 0.0064 | 0.0064 | 0.0128 | 0.0634 | 0.500 | „ |
| Unmolassed | ... | ... | ... | 0.0532 | 0.422 | 10-1-06 |
| Molassed | 0.0064 | 0.0064 | 0.00128 | 0.0638 | 0.489 | „ |
| Unmolassed | 0.00424 | 0.007 | 0.01124 | 0.0532 | 0.422 | 11-8-36 |
| Molassed | 0.00622 | 0.0066 | 0.01282 | 0.06349 | 0.4899 | „ |
| Unmolassed | 0.0042 | 0.007 | 0.0112 | 0.0532 | 0.434 | 30-4-36 |
| Molassed | 0.006 | 0.0066 | 0.0126 | 0.0635 | 0.489 | „ |

TABLE 51.

34.65 kg. of nitrogen as (NH₄)₂SO₄ per acre of land used and 3000 kilograms molasses per acre.

| | | | | | | |
|------------|----------|----------|---------|---------|--------|----------|
| Unmolassed | 0.01206% | 0.00344% | 0.0155% | 0.0603% | 0.417% | 27-9-35 |
| Molassed | 0.01228 | 0.00344 | 0.01572 | 0.0608 | 0.587 | „ |
| Unmolassed | 0.00768 | 0.00636 | 0.01404 | 0.0609 | 0.416 | 12-10-35 |
| Molassed | 0.01076 | 0.00436 | 0.01512 | 0.0636 | 0.573 | „ |
| Unmolassed | 0.00754 | 0.00636 | 0.01390 | 0.0593 | 0.421 | 24-10-35 |
| Molassed | 0.0100 | 0.00636 | 0.01636 | 0.0673 | 0.507 | „ |
| Unmolassed | 0.00538 | 0.00776 | 0.01314 | 0.0583 | 0.418 | 7-11-35 |
| Molassed | 0.00896 | 0.00874 | 0.0177 | 0.0667 | 0.502 | „ |
| Unmolassed | 0.00502 | 0.0078 | 0.01282 | 0.0583 | 0.418 | 13-12-35 |
| Molassed | 0.0088 | 0.0088 | 0.0176 | 0.0667 | 0.500 | „ |
| Unmolassed | 0.00488 | 0.008 | 0.01288 | 0.574 | 0.422 | 10-1-36 |
| Molassed | 0.008 | 0.008 | 0.016 | 0.067 | 0.512 | „ |
| Unmolassed | 0.00464 | 0.0082 | 0.01284 | 0.0572 | 0.422 | 11-3-36 |
| Molassed | 0.00644 | 0.0082 | 0.01464 | 0.668 | 0.509 | „ |
| Unmolassed | 0.0045 | 0.0082 | 0.0127 | 0.0572 | 0.434 | 30-4-36 |
| Molassed | 0.006 | 0.0084 | 0.0144 | 0.0668 | 0.509 | , |

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TABLE 52.

| Condition. | NH ₃ N. | NO ₃ -N. | Available-N. | Total-N. | Total-C. | Date of analysis. |
|------------|--------------------|---------------------|--------------|----------|----------|-------------------|
| Unmolassed | 0.02032% | 0.00356% | 0.02388% | 0.0757% | 0.416% | 27-9-35 |
| Molassed | 0.02044 | 0.00384 | 0.02428 | 0.0757 | 0.585 | " |
| Unmolassed | 0.00874 | 0.00932 | 0.01806 | 0.0700 | 0.416 | 12-10-35 |
| Molassed | 0.0140 | 0.00636 | 0.02036 | 0.0760 | 0.574 | " |
| Unmolassed | 0.00754 | 0.01040 | 0.01794 | 0.0636 | 0.416 | 24-10-35 |
| Molassed | 0.01272 | 0.00874 | 0.02146 | 0.0823 | 0.574 | " |
| Unmolassed | 0.00636 | 0.01166 | 0.01802 | 0.0612 | 0.422 | 7-11-35 |
| Molassed | 0.0100 | 0.00972 | 0.01972 | 0.0828 | 0.552 | " |
| Unmolassed | 0.00578 | 0.01116 | 0.01738 | 0.061 | 0.422 | 13-12-35 |
| Molassed | 0.0096 | 0.0098 | 0.0194 | 0.0830 | 0.542 | " |
| Unmolassed | 0.0056 | 0.01144 | 0.01704 | 0.0596 | 0.422 | 10-1-36 |
| Molassed | 0.008 | 0.0100 | 0.0180 | 0.0842 | 0.532 | " |
| Unmolassed | 0.0047 | 0.01176 | 0.01646 | 0.0595 | 0.4284 | 11-3-36 |
| Molassed | 0.0056 | 0.010566 | 0.01712 | 0.0844 | 0.5312 | " |
| Unmolassed | 0.0044 | 0.0117 | 0.0161 | 0.0595 | 0.428 | 30-4-36 |
| Molassed | 0.006 | 0.0106 | 0.0166 | 0.0811 | 0.5321 | " |

TABLE 53.

138.60 kg. of nitrogen as $(\text{NH}_4)_2\text{SO}_4$ per acre of land used and 3000 kilograms molasses per acre

| Condition. | $\text{NH}_3\text{-N.}$ | $\text{NO}_3\text{-N}$ | Available. -N | Total-N. | Total-C. | Date of analysis. |
|------------|-------------------------|------------------------|------------------|----------|----------|----------------------|
| Unmolassed | 0.032% | 0.0028% | 0.0348% | 0.14% | 0.476% | 18-1-36 |
| Molassed | 0.032 | 0.0028 | 0.0348 | 0.14 | 0.7435 | , |
| Unmolassed | 0.0080 | 0.00934 | 0.01734 | 0.1081 | 0.4812 | 30-1-36 |
| Molassed | 0.0112 | 0.00972 | 0.02092 | 0.1179 | 0.7452 | , |
| Unmolassed | 0.00582 | 0.01132 | 0.01714 | 0.1032 | 0.478 | 19-2-36 |
| Molassed | 0.0100 | 0.0100 | 0.020 | 0.1185 | 0.7442 | , |
| Unmolassed | 0.00504 | 0.01194 | 0.01698 | 0.0995 | 0.478 | 9-3-36 |
| Molassed | 0.00984 | 0.0102 | 0.02004 | 0.1172 | 0.744 | , |
| Unmolassed | 0.00416 | 0.01224 | 0.0164 | 0.0982 | 0.478 | 4-4-36 |
| Molassed | 0.00956 | 0.01048 | 0.0200 | 0.1092 | 0.742 | , |
| Unmolassed | 0.00324 | 0.01302 | 0.01626 | 0.09212 | 0.478 | 25-4-36 |
| Molassed | 0.00896 | 0.01104 | 0.02 | 0.1012 | 0.743 | , |

TABLE 54.

277.2 kg. of nitrogen as $(\text{NH}_4)_2\text{SO}_4$ per acre of land used and 300 kilograms molasses per acre.

| | | | | | | |
|------------|---------|---------|---------|--------|--------|---------|
| Unmolassed | 0.0468% | 0.0028% | 0.0496% | 0.200% | 0.476% | 18-1-36 |
| Molassed | 0.0468 | 0.0028 | 0.0496 | 0.200 | 0.743 | , |
| Unmolassed | 0.0234 | 0.01468 | 0.03808 | 0.167 | 0.481 | 30-1-36 |
| Molassed | 0.029 | 0.01504 | 0.04404 | 0.1866 | 0.745 | , |
| Unmolassed | 0.020 | 0.01488 | 0.03488 | 0.1425 | 0.478 | 19-2-36 |
| Molassed | 0.0294 | 0.01510 | 0.0445 | 0.1788 | 0.744 | , |
| Unmolassed | 0.01844 | 0.01544 | 0.03388 | 0.1325 | 0.478 | 9-3-36 |
| Molassed | 0.02774 | 0.01462 | 0.04236 | 0.1725 | 0.744 | , |
| Unmolassed | 0.01784 | 0.0157 | 0.03354 | 0.1281 | 0.472 | 4-4-36 |
| Molassed | 0.248 | 0.0164 | 0.0412 | 0.170 | 0.743 | , |
| Unmolassed | 0.00862 | 0.01848 | 0.0271 | 0.1122 | 0.472 | 25-4-36 |
| Molassed | 0.01856 | 0.02024 | 0.0388 | 0.1642 | 0.742 | , |

Thus with 138.6 kg. of nitrogen as ammonium sulphate per acre of land, the loss of nitrogen amounts to 34.2% in the absence of molasses whilst with molasses it is 27.1%; with 277.2 kg. of nitrogen the loss is 43.9% without molasses with molasses, the loss is only 17.9%.

TABLE 55.

Retardation of nitrogen loss from soil with cow-dung, green leaves and molasses.

17.325 kgms. of nitrogen as $(\text{NH}_4)_2 \text{SO}_4$ per acre of land used.

| Condition. | $\text{NH}_3\text{-N}$ | $\text{NO}_3\text{-N}$ | Total-N. | Total-C, | Date of Analysis |
|------------|------------------------|------------------------|----------|----------|------------------|
| Alone | 0.0018% | 0.0028% | 0.0583% | 0.3654% | 6-10-36 |
| Cow-dung | 0.002 | 0.0029 | 0.0583 | 0.502 | " |
| Leaves | 0.0018 | 0.0028 | 0.056 | 0.4532 | " |
| Molasses | 0.0014 | 0.0028 | 0.056 | 0.7281 | " |
| Alone | 0.0014 | 0.0031 | 0.05 | 0.365 | 24-10-36 |
| Cow-dung | 0.0016 | 0.0032 | 0.0583 | 0.5012 | " |
| Leaves | 0.0017 | 0.0031 | 0.05 | 0.4641 | " |
| Molasses | 0.0016 | 0.0028 | 0.0583 | 0.7124 | " |
| Alone | 0.0012 | 0.0032 | 0.05 | 0.3632 | 12-11-36 |
| Cow-dung | 0.0018 | 0.003 | 0.0594 | 0.5010 | " |
| Leaves | 0.0016 | 0.003 | 0.053 | 0.4632 | " |
| Molasses | 0.0016 | 0.0029 | 0.0583 | 0.7028 | " |
| Alone | 0.0012 | 0.0032 | 0.0472 | 0.3642 | 26-11-36 |
| Cow-dung | 0.0018 | 0.003 | 0.0584 | 0.4998 | " |
| Leaves | 0.0016 | 0.003 | 0.0626 | 0.4832 | " |
| Molasses | 0.0016 | 0.003 | 0.0586 | 0.0912 | " |
| Alone | 0.0008 | 0.0034 | 0.0478 | 0.3652 | 30-12-36 |
| Cow-dung | 0.0008 | 0.0036 | 0.0511 | 0.4897 | " |
| Leaves | 0.0012 | 0.0032 | 0.0667 | 0.4944 | " |
| Molasses | 0.0012 | 0.0033 | 0.056 | 0.5112 | " |

TABLE 56.

Retardation of nitrogen loss from soil with cow-dung, green leaves, and molasses
277.2 kg. of nitrogen as $(\text{NH}_4)_2\text{SO}_4$ per acre of land used.

| Condition. | NH ₃ -N. | NO ₃ -N. | Total-N. | Total-C | Date of Analysis |
|------------|---------------------|---------------------|----------|---------|------------------|
| Alone | 0.028% | 0.0026% | 0.1167% | 0.3721% | 6-10-36 |
| Cow-dung | 0.035 | 0.003 | 0.1272 | 0.5046 | " |
| Leaves | 0.0304 | 0.0026 | 0.1137 | 0.3731 | " |
| Molasses | 0.028 | 0.0031 | 0.1272 | 2.435 | " |
| Alone | 0.0242 | 0.0039 | 0.100 | 0.3738 | 24-10-36 |
| Cow-dung | 0.0324 | 0.0036 | 0.1082 | 0.5044 | " |
| Leaves | 0.0236 | 0.0042 | 0.100 | 0.3792 | " |
| Molasses | 0.0296 | 0.0030 | 0.1167 | 2.421 | " |
| Alone | 0.0222 | 0.004 | 0.0875 | 0.3722 | 12-11-36 |
| Cow-dung | 0.0304 | 0.0039 | 0.100 | 0.5010 | " |
| Leaves | 0.0232 | 0.0049 | 0.0903 | 0.3812 | " |
| Molasses | 0.0294 | 0.0054 | 0.1158 | 2.301 | " |
| Alone | 0.0182 | 0.0061 | 0.0823 | 0.3768 | 26-11-36 |
| Cow-dung | 0.0196 | 0.0062 | 0.0934 | 0.498 | " |
| Leaves | 0.0194 | 0.0073 | 0.0908 | 0.431 | " |
| Molasses | 0.0248 | 0.006 | 0.1346 | 1.424 | " |
| Alone | 0.0017 | 0.0064 | 0.0583 | 0.3712 | 30-12-36 |
| Cow-dung | 0.0019 | 0.0078 | 0.0736 | 0.4882 | " |
| Leaves | 0.0017 | 0.0082 | 0.0712 | 0.5122 | " |
| Molasses | 0.004 | 0.0097 | 0.1273 | 0.9864 | " |

The Tables 55 and 56 show that the loss of nitrogen by the addition of ammonium sulphate to the field soil is also lessened by the addition of carbonaceous substances like cow-dung, leaves etc. With molasses and ammonium sulphate, there is nitrogen fixation.

FUNCTION OF ORGANIC MANURES

It will be clear, therefore, that the value of ammonium sulphate as a manure to be used in tropical countries should be greatly enhanced, if it is mixed with cow-dung, leaves, molasses, fats or any other carbonaceous material. Oil cake containing fats and nitrogenous compounds has been found to be effective in tropical countries as nitrogenous manures, because fats are known to retard the

oxidation and nitrification of the nitrogenous compounds in the soil. It is clear, why farmyard or green manure, produces better crop yield than ammonium sulphate alone, because the carbonaceous substances present in the farmyard or green-manure, retard the nitrification of the nitrogenous compounds present in the soil and decrease the nitrogen loss. As a matter of fact, when farmyard manure is added to the soil more nitrogen is conserved and fixed in the soil than with ammonium sulphate. This is evident from the following important results obtained from the Rothamsted fields :—

| | Total N. |
|--|----------|
| 1. Receiving no manure since 1843 ... | 0.095% |
| 2. Receiving farmyard manure since 1852 ... | 0.256 |
| 3. Receiving complete artificials : $(\text{NH}_4)_2\text{SO}_4$... | 0.099 |
| 4. Receiving complete artificials + farmyard manure ... | 0.253 |
| 5. Receiving potash and phosphate but no nitrogen ... | 0.090 |

Of course, too little oxidation of the protein present in the soil by the addition of molasses will not make the soil suitable for the growth of crops. It seems necessary that an equilibrium should be established between the oxidised and the unoxidised proteins, ammonium salts and other nitrogenous substances, which are present in the soil for maintaining its fertility at a proper level. Too much oxidation of the nitrogenous substances and ammonium salts may entail marked nitrogen loss by this type of denitrification and too little oxidation will not make the soil fertile enough for a good yield of crop. Hence the molasses or cellulosic materials or other carbonaceous substances should not be added in very large amounts and after the addition of molasses or other substances, the soil should be ploughed to help oxidation. Moreover, molasses and cellulosic materials when added to soil and the soil is properly aerated for helping the oxidation reactions, cause nitrogen fixation by the increase of ammoniacal and total nitrogen contents of soil.

This type of nitrogen loss may amount to 100 lbs. of nitrogen per acre annually, whilst the amount of nitrogen required by wheat (for example), per acre is 30-40 lbs. Russell and his co-workers at Rothamsted have reported that during 47 years of application of manure to soil, 14 per cent of the nitrogen was accumulated as humus, 25 per cent had been utilized by the plants and 60 per cent was lost in the gaseous state i. e. aerobic denitrification. Hence it is highly important to investigate this phenomenon and control this loss for increasing soil fertility.

The greater value of organic nitrogenous compounds or a mixture of ammonium salts and carbonaceous substances for the soil than ammonium salts lies in the fact that not only the soil texture is improved by the colloids added with the organic manure but the carbonaceous matter added acts as an agent in the preservation of the nitrogenous compounds of the soil by behaving as a negative catalyst.

Apart from this influence of the carbonaceous substances, sugars, cellulose, pentosans, fats, etc. on the conservation of soil nitrogen, these substances when added to the soil along with farmyard or green manure, or straw, also leads to the fixation of atmospheric nitrogen in the soil. Hence the carbonaceous substances, like sugars, cow-dung, cellulose, pentosans, fats, etc. added to the soil are not only effective in nitrogen conservation but cause nitrogen fixation as well. In a recent article Jenkins (Imp. Bur. Soil. Sci. Tech. Com. No. 33, 1935) has discussed the use of organic manures but has not reported that organic manures help in the conservation and fixation of nitrogen in the soil. This aspect of the importance of organic manures in preference to artificials has been discovered by the present writer.

The foregoing results show that when 17.32 to 69.3 kgs. of nitrogen as ammonium sulphate are added per acre of soil along with molasses, there is appreciable nitrogen fixation in the soil even in the presence of ammonium sulphate, as the total nitrogen at the end in the fields containing ammonium sulphate and molasses is always greater than at the beginning. These results cannot be explained from the bacterial view point of nitrogen fixation, because it has been assumed that in presence of ammonium salt hardly any bacterial nitrogen fixation is possible. Hence our results showing an increase of nitrogen, when molasses is added to fields to which ammonium sulphate has already been added support the view, that nitrogen fixation is partly bacterial and partly photochemical and catalytic.

NITROGEN FIXATION IN SOILS CONTAINING NITROGENOUS COMPOUNDS.

It is generally believed that bacterial nitrogen fixation is inhibited when nitrates, ammonium sulphate etc., are already present in the soil. This view has been emphasised by Waksman in his "Soil Microbiology" page 505, 1931:—"Nitrates are readily utilised by Azotobacter as sources of nitrogen; accordingly the presence of nitrates in the medium inhibits the fixation of

atmospheric nitrogen. Ammonium sulphate and peptone are also available nitrogen compounds. One half milligram of nitrogen in an available form is sufficient to inhibit completely the fixation process."

Recently Fuller and Rettger (Soil. Sci. 31 219. 1931) have reported that in presence of ammonium sulphate and potassium nitrate nitrogen fixation was considerably retarded by several strains of Azotobacter chroococcum in culture media but several nitrogenous compounds did not affect materially the nitrogen fixation. These authors have concluded in agreement with Bonazzi and others (Jour. Bact. 6, 331 1921) that Azotobacter utilizes available combined nitrogen where possible instead of following the more laborious process of fixing free nitrogen.

We have carried on systematic work on the fixation of atmospheric nitrogen in fields or dishes supplied with nitrogenous compounds like oilcakes, urea, gelatine, blood etc., with and without molasses. Our observations show that there is appreciable nitrogen fixation both in plots and dishes containing different nitrogenous substances and molasses.

The following results have been obtained with oilcakes, containing 5.71 to 6.03% of nitrogen.

TABLE 57.
NITROGEN FIXATION WITH OIL CAKES

Experiments in fields

| 10 tons of oil cakes with or without 2 tons molasses per acre of land. | | | | |
|--|----------------------------------|--|--|---|
| | Originally present on | Analysed on | Analysed on | Analysed on |
| | 18-9-36 | 9-10-36 | 14-11-36 | 24-12-36 |
| Mustard oil cake | C-0.6376 N-0.1520 C:N=4.19 | C-0.43920 N-0.13590 NO ₃ -0.00700 NH ₃ -0.00482 C:N=3.23 | C-0.41400 N-0.11870 NO ₃ -0.01836 NH ₃ -0.00222 C:N=3.23 | C-0.4067 N-0.1102 NO ₃ -0.02058 NH ₃ -0.0195 C:N=3.68 |

| | | | |
|------------------------|--------------------------|--------------------------|--------------------------|
| Mustard oil C = 0·7504 | C = 0·67680 | C = 0·55080 | C = 0·36000 |
| oil cake + N = 0·1485 | N = 0·15050 | N = 0·15730 | N = 0·16470 |
| Molasses C:N = 5·05 | NO ₃ -0·00823 | NO ₃ -0·01571 | NO ₃ -0·02333 |
| | NH ₃ -0·00848 | NH ₃ -0·00325 | NH ₃ -0·0225 |
| | C:N = 4·9 | C:N = 3·51 | C:N-2·18 |
| Neem oil C = 0·7025 | C = 0·6000 | C = 0·72960 | C = 0·4560 |
| oil cake N = 0·18133 | N = 0·1707 | N = 0·1573 | N = 0·1060 |
| Molasses C:3·874 | NH ₃ -0·00373 | NH ₃ -0·01555 | NH ₃ -0·00254 |
| | NO ₃ -0·00636 | NO ₃ -0·01077 | NO ₃ -0·02333 |
| | C:N = 4·1 | C:N = 4·63 | C:N-4·3 |
| Neem oil C = 1·0763 | C = 0·82560 | C = 0·8160 | C = 0·7560 |
| oil cake + N = 0·1826 | N = 0·24560 | N = 0·2641 | N = 0·18660 |
| Molasses C:N = 5·89 | NO ₃ -0·00528 | NO ₃ -0·01037 | NO ₃ -0·03180 |
| | NH ₃ -0·01031 | NH ₃ -0·00304 | NH ₃ -0·00239 |
| | C:N = 3·36 | C:N-3·1 | C:N4·05 |

TABLE 58.

Experiments in dishes with alkali soils (pH = 10·8.)

| | Analysed on | Analysed on |
|--|-------------|-------------|
| Mustard oil cake 50 grms } Exposed 13-11-36 soil 500 grms } to C = 3·2400 14-12-36 } light N = 0·3862 C = 2·0160 } NH ₃ =0·00800 N = 0·3111 } NO ₃ =0·01400 NH ₃ =0·0053 } C : N = 8·39 NO ₃ =0·0133 } C : N = 6·67 | | |
| Mustard oil cake 50 grams } Exposed C = 5·0160 C = 2·1120 soil 500 grams } to N = 0·2800 N = 0·4000—F molasses 50 grams } light NH ₃ =0·0063 NH ₃ =0·00417 } NO ₃ =0·0133 NO ₃ =0·01555 } C : N = 14·32 C : N = 5·27 | | |

TABLE 59.

500 gms. alkali soil ($\text{pH}=10.8$) + 1gm. CaCO_3 + molasses.

| | C | N | C:N | Date of analysis |
|---------------------|---------|--------|------|------------------|
| Original | 0.2782% | 0.025% | 11.1 | 27-7-36 |
| 1. 2 gms. molasses | 0.2821 | 0.028 | 10.0 | 21-8-36 |
| 2. 4 gms. molasses | 0.3025 | 0.031 | 9.7 | " |
| 3. 8 gms. molasses | 0.3348 | 0.0317 | 10.5 | " |
| 4. 16 gms. molasses | 0.5189 | 0.0388 | 13.3 | " |
| 5. 32 gms. molasses | 0.7365 | 0.0437 | 16.8 | " |
| 6. 40 gms. molasses | 0.9728 | 0.0518 | 18.7 | " |
| 1. 2 gms. molasses | 0.2812 | 0.028 | 10.0 | 22.9-36 |
| 2. 4 gms. molasses | 0.2912 | 0.0312 | 9.3 | " |
| 3. 8 gms. molasses | 0.3233 | 0.0324 | 9.9 | " |
| 4. 16 gms. molasses | 0.4952 | 0.0392 | 12.6 | " |
| 5. 32 gms. molasses | 0.6944 | 0.0447 | 15.6 | " |
| 6. 40 gms. molasses | 0.8287 | 0.0532 | 15.4 | " |
| 1. 2 gms. molasses | 0.2427 | 0.0269 | 9.0 | 19-11-36 |
| 2. 4 gms. molasses | 0.2678 | 0.0318 | 8.4 | " |
| 3. 8 gms. molasses | 0.2678 | 0.0328 | 8.1 | " |
| 4. 16 gms. molasses | 0.2678 | 0.0398 | 6.9 | " |
| 5. 32 gms. molasses | 0.2721 | 0.045 | 6.0 | " |
| 6. 40 gms. molasses | 0.2788 | 0.0541 | 5.1 | " |

The foregoing results with oil cakes show that in presence of molasses there is appreciable nitrogen fixation with mustard and neem oil cakes, although in the absence of molasses these cakes lose nitrogen, apparently by aerobic denitrification. A very important result is brought out by these experiments in which it is observed that when the carbon-nitrogen ratio of the soil containing a mixture of oilcakes and molasses is even as low as 5.05 there is appreciable nitrogen fixation.

Similar results have been obtained in fields containing a mixture of ammonium sulphate and molasses. It has been observed that in several of these fields containing both ammonium sulphate and molasses there is appreciable nitrogen fixation because the total nitrogen present in the soil at

the end is always greater than at the beginning. The results recorded in Tables 50, 51 and 52 show that the carbon-nitrogen ratio at the beginning were 7.7, 9.6, and 10 respectively, whilst in the end the ratios became 6.7, 7.5 and 7.8 respectively. On the other hand, the results in Tables 53 and 54 show that when the carbon-nitrogen ratios were 5.3 and 3.7 in the beginning, there was no nitrogen fixation, as the carbon-nitrogen ratio in these plots rose to 7.3 and 4.5 respectively. It appears, therefore, that fairly large amounts of nitrogen fixation is observed in plots containing oilcakes and molasses even when the carbon-nitrogen ratio is about 5, whilst with ammonium sulphate and molasses, nitrogen fixation is possible when the carbon-nitrogen ratio is about 7.

The results recorded in Tables 59 and 61 show that alkaline soils containing molasses kept in dishes can also fix nitrogen even when the carbon-nitrogen ratio is round about 10 or less. When the carbon-nitrogen ratio is greater than 10, there is more marked fixation of nitrogen. In view of the foregoing experimental observations proving the possibility of nitrogen fixation in soils, both normal and alkaline with low carbon-nitrogen ratio, the usually accepted significance of carbon-nitrogen ratio as stated by Russell (Soil Conditions and Plant Growth 313, 1932), in the following words has to undergo modification.

"The changes affecting the carbon and those affecting the nitrogen are intimately associated. The nitrogen can appear as nitrate only if it exceeds a certain critical amount relatively to the carbon—usually if the ratio C/N is 12 or less. When the proportion of carbon is greater, the excess goes off as CO_2 and the nitrogen remains as complex protein, any ammonia or nitrate present is also converted into protein, when, on the other hand, the proportion of nitrogen becomes greater the excess is changed into nitrate. This intimate relationship arises from the fact that the decomposition of the organic matter is brought about by microorganisms."

Our observations showing appreciable nitrogen fixation in soils already containing 0.15% nitrogen or more, cannot be explained from the bacterial view point of nitrogen fixation. It appears that the photochemical and catalytic oxidation of the carbohydrates present in molasses liberates energy necessary for nitrogen fixation. This process of photochemical and catalytic nitrogen fixation can take place even when nitrogenous substances are already present in the soil. These results in which bacterial nitrogen fixation has been considerably inhibited by the presence of nitrogenous compounds like oilcakes, ammonium sulphate etc., support the view point that nitrogen fixation may be bacterial as well as photochemical and catalytic.

ALKALI SOILS AND THEIR RECLAMATION.

There are vast tracts of alkaline land in India. It is estimated that the total area of alkaline land in the United Provinces alone is over four million acres. In the Punjab, Behar, Mysore, Sind, Bombay and Madras Presidencies, there are large areas of such unproductive land. In Sind and in other parts of the country normal soils are being converted into alkaline ones by the washing away of the soil due to irrigation water. Moreover, there are large areas of sea-water-damaged lands in Bengal, Gujarat, Bombay and Madras Presidencies. Due to various causes, some of which, are discussed later on, the amount of alkaline land is increasing in India.

In my last address I pointed out that the crop yield in India is very poor, chiefly due to nitrogen deficiency of the soil. Moreover, figures show that only 0·75 acre of land under cultivation is available per head of the population in India as against 2·6 acres in U. S. A. and 2·3 acres in France. Hence we have to face the staggering evidence that we have in this country very little land for a unit of population. Hence land reclamation is of vital importance for the welfare of the masses in India.

In the last address it was reported that when molasses is added to alkaline soils, the alkalinity is destroyed and the soil assumes the characteristics of normal soils and good rice crop has been obtained from such reclaimed land. Further work in the reclamation of alkali land is in progress in these laboratories and some of our results are presented here.

DEFECTS OF ALKALI LANDS.

The chief defects of alkali land are:—

1. The alkalinity.—We have examined several samples of bad alkali soils and we find that the pH is as high as 10·8. Neither Azotobacter nor nitrite-formers are observed in cultures obtained with these soils.
2. The amount of calcium compounds is less in these soils than in normal ones. The amounts of exchangeable bases are less than in normal soils.
3. The nitrogen content is small. In several samples examined by us the total nitrogen varied from 0·008 to 0·02%, normal soils in India contain approximately 0·05% nitrogen. The carbon content is also low,

4. The alkali soil is highly impermeable to water.
5. The alkali soil particles do not settle readily when shaken with water.
6. The alkali soil lacks bacterial activity.

RECLAMATION OF ALKALI SOIL BY PRESSMUD.

It appears that nearly 300,000–400,000 tons of pressmud are being turned out by the sugar factories in India. This substance containing calcium salts, carbohydrates, and nitrogenous compounds are practically wasted. Our results show that when bad alkali soils ($\text{pH}=10.8$), are mixed with pressmud, the pH becomes much less and the alkali soils completely coagulate, showing increased permeability and flocculation of the particles. The calcium salts present in the pressmud convert the sodium soil into a calcium one. It appears, therefore, that the pressmud also is an excellent reclaiming agent for alkali soils. As pressmud is a solid substance and easy to transport, it should be largely utilised in reclaiming alkali soils.

RECLAMATION OF ALKALI SOILS BY OIL CAKES.

Oil cakes containing about 5 to 7% nitrogen, oils, and cellulosic materials, have been found to neutralise the alkalinity of bad alkali soils. Hence oil cakes should be suitable reclaiming agents. It has been emphasised, that the chief defects of the alkali soils are high alkalinity, deficiency of nitrogen, organic matter, calcium, low permeability etc. Also most alkali soils lack bacterial activity. In most Indian alkali soils, the calcium content is not much less than that present in normal soils. The addition of oil cakes (Linseed, Mustard, Rape and Neem) has been found to remove the chief defects of an alkali soil and these are being utilised in reclaiming bad alkali soils.

Pot experiments with pressmud and oil cakes (containing 1–2 parts of reclaiming agent in 100 parts of alkali soil of $\text{pH } 10.8$) as reclaiming agents show that rice plants can grow well in very bad alkali soils when mixed with pressmud or oil cakes and watered,

FIELD TRIALS.

Last year, the Agriculture Department of the Mysore Government applied to several fields 1 ton of molasses per acre of alkali land three weeks before the transplantation of rice. 1200-1800 lbs of rice grains per acre of alkali soil were obtained in the molassed fields where the crop completely failed in previous years. The normal production of rice in India is 1295 lbs per acre. As this Government is highly satisfied with these results they have extended their trial to 100 acres of alkali soil.

In the United Provinces molasses has been utilised in reclaiming alkali land at Soraon near Allahabad, Government Farm, Unao, Shahjehanpur and Cawnpore, and in all these places, excellent rice crop has been obtained in bad alkaline fields, where no vegetation ever grew. Using 3 to 10 tons of molasses per acre of land good results have been obtained even on bad alkali land. The amount of molasses to be added depends on the nature of the alkali soil.

Recently Mr. H. N. Batham working at Cawnpore and Dr. Mirchandani working at Sabour, Behar, have confirmed our results and show that molasses is an excellent reclaiming agent even for bad alkali soils. At our suggestion the Agricultural Chemists at Padegaon (Bombay), Cawnpore, Rohtak (Punjab) and other places are reclaiming alkaline land by the application of molasses.

Mixtures of molasses with pressmud in different proportions have been found to be very effective in reclaiming bad alkali soils. Using 10 tons of molasses per acre of very bad alkali soil ($pH = 10.8$) at Soraon (Allahabad), 600 lbs of rice grains were obtained. The land had been entirely barren before the addition of molasses.

As molasses contains 2% lime, the alkali soil, which is a sodium soil, is converted into a calcium soil which is a normal one, when molasses or a mixture of molasses and pressmud is added to an alkali soil. As the sodium of the alkali soil is mainly replaced by calcium on the addition of molasses, the reclamation seems to be permanent. Land reclaimed by molasses has been found to be able to produce rice for two years or more without further application of molasses. In the last address, the work on alkali soil carried on in Europe and America has been briefly summarised but the views advanced so far do not adequately explain the formation of alkali soil under Indian conditions. In this address new conceptions regarding the formation of alkali soils are advanced,

HOW A NORMAL SOIL CAN BECOME ALKALINE IN INDIA ?

1. It is well known that when a plant is burnt in air, alkali carbonates are left as residue. On the soil surface, similar oxidations take place at a small velocity. The carbonaceous and nitrogenous substances of the plant are steadily oxidized leaving only alkaline mineral residues. Hence the plants and their residues present in the soil can add alkali to the normal soil. It is well known that green manuring increases the alkalinity of a soil. Hence normal soils in tropical countries may become alkaline due to the oxidation and loss of the carbonaceous and nitrogenous portions of the organic substances. It is of interest to note here that the pH of soils collected from different countries are as follows:—

| Country | pH. |
|--------------|-------------|
| Scotland ... | ... 5—6·4 |
| Finland ... | ... 5—6·4 |
| Japan ... | ... 4·5—6·9 |
| Denmark ... | ... 6—6·9 |
| Sweden ... | ... 6—7·4 |
| Java ... | ... 6·5—7·9 |
| Egypt ... | ... 7—9 |
| North India | ... 7—10·8 |

2. Experimental results obtained in different countries show that the exchangeable calcium varies from 63—92% of the total calcium of the normal soil. At Allahabad this percentage is 76%. On the other hand, the exchangeable sodium or potassium does not exceed 11% of the total. Hence when a normal soil is washed even with distilled water, more calcium is likely to be washed away than sodium or potassium. A sample of normal soil containing 1.21% CaO and 1.115% Na₂O, was washed with distilled water and the filtrate contained 0.025% CaO and 0.0115% Na₂O. Hence washing removes more calcium than sodium from a soil. It is well known that a normal soil is usually a calcium one and an alkaline soil is sodium soil. In other words, when the exchangeable calcium of a normal soil is washed away to a greater extent, the calcium soil will gradually pass into a sodium soil, which when hydrolysed produces sodium hydroxide. The carbonic acid of the air by interaction with sodium hydroxide forms sodium

carbonate and bicarbonate. If the rain water or irrigation water washes away a normal soil year after year and the washed water is not retained by the soil, there is always the possibility of the formation of alkali soils from normal ones. According to this view point, for the conversion of normal soils to alkaline ones the soils need not be treated with sea water or saline water, but even repeated washing by rain or good irrigation water may cause alkalinity of a normal soil. These considerations are in general agreement with the actual occurrence of *Usar* (alkaline) soils in different parts of the United Provinces and Madras Presidency.

TABLE 60.

Experiments on the change of pH values and nitrogen contents of alkaline soil treated with a mixture of molasses and pressmud.
started on 26-8-36.

| Condition | pH. | NH ₃ -N. | NO ₃ -N. | Total-N. | Total-C. |
|-----------------------|------|---------------------|---------------------|----------|----------|
| Original alkali soil. | 10.8 | 0.001% | 0.0018% | 0.0256% | 0.2678% |

ANALYSED ON 11-9-36.

| | | | | | |
|--|-----|--------|--------|--------|--------|
| 50 gms. molasses + 100 gms pressmud per kilogram soil | 6.8 | 0.0014 | 0.0021 | 0.0636 | 1.774 |
| 50 gms. molasses + 50 gms pressmud per kilogram soil | 7.0 | 0.002 | 0.0021 | 0.0538 | 1.028 |
| 100 gms. molasses + 50 gms. pressmud per kilogram soil | 6.8 | 0.0023 | 0.0021 | 0.07 | 1.6059 |
| 100 gms. molasses + 100 gms. pressmud per kilogram soil | 6.8 | 0.003 | 0.0021 | 0.078 | 1.9831 |
| 25 gms. molasses + 25 gms pressmud per kilogram soil | 7.2 | 0.0013 | 0.0021 | 0.0412 | 0.6517 |
| 200 gms. molasses + 200 gms. pressmud per kilogram soil | 6.4 | 0.0046 | 0.0021 | 0.14 | 4.932 |
| 200 gms. molasses + 100 gms pressmud per kilogram soil | 6.8 | 0.004 | 0.0023 | 0.127 | 8.894 |

ANALYSED ON 7-11-36.

| | | | | | |
|--|-----|--------|--------|--------|--------|
| 50 gms. molasses + 100 gms. pressmud per kilogram soil | 6.6 | 0.0022 | 0.0024 | 0.0717 | 1.168 |
| 50 gms molasses + 50 gms. pressmud per kilogram soil | 6.8 | 0.0037 | 0.0026 | 0.0588 | 0.5758 |
| 100 gms. molasses + 50 gms. pressmud per kilogram soil | 6.6 | 0.004 | 0.0027 | 0.0719 | 1.127 |
| 100 gms. molasses + 100 gms. pressmud per kilogram soil | 6.6 | 0.006 | 0.0028 | 0.0934 | 1.377 |
| 25 gms. molasses + 25 gms. pressmud per kilogram soil | 7.0 | 0.0028 | 0.0023 | 0.0485 | 0.5822 |
| 200 gms. molasses + 200 gms. pressmud per kilogram soil | 6.2 | 0.0064 | 0.0035 | 0.14 | 2.551 |
| 200 gms. molasses + 100 gms. pressmud per kilogram soil | 6.2 | 0.0049 | 0.005 | 0.132 | 1.506 |

TABLE 61

Experiments carried on with alkali soil ($\text{pH} = 10.8$) and molasses made
into heaps.

| Available-N. | Total-N. | Total-C. | C : N | Date of Analysis |
|--|----------|----------|--------|------------------|
| 6½ kilograms of molasses per 100 kilograms of soil | 0.0056% | 0.0583% | 2.287% | 738.9 5-3-36 |
| 12½ kilo „ 100 kilo „ | 0.00732 | 0.0934 | 4.2661 | 45.6 „ |
| 25 kilo „ 100 kilo „ | 0.00774 | 0.1261 | 8.2512 | 67.0 „ |
| 6½ kilo „ 100 kilo „ | 0.0044 | 0.0652 | 1.7281 | 26.5 27-3-36 |
| 12½ kilo „ 100 kilo „ | 0.0086 | 0.099 | 3.576 | 38.0 „ |
| 25 kilo „ 100 kilo „ | 0.0134 | 0.1452 | 8.00 | 55.6 „ |
| 6½ kilo „ 100 kilo „ | 0.00588 | 0.0692 | 1.325 | 19.1 17-4-36 |
| 12½ kilo „ 100 kilo „ | 0.0095 | 0.1152 | 2.781 | 24.1 „ |
| 25 kilo „ 100 kilo „ | 0.01712 | 0.1522 | 7.032 | 46.2 „ |
| 6½ kilo „ 100 kilo „ | 0.00576 | 0.0712 | 1.125 | 15.8 28-4-36 |
| 12½ kilo „ 100 kilo „ | 0.0104 | 0.1212 | 2.622 | 21.5 „ |
| 25 kilo „ 100 kilo „ | 0.01695 | 0.1528 | 7.00 | 44.6 „ |
| 6½ kilo „ 100 kilo „ | 0.0072 | 0.0785 | 0.885 | 11.3 10-7-36 |
| 12½ kilo „ 100 kilo „ | 0.0118 | 0.1428 | 1.562 | 10.9 „ |
| 25 kilo „ 100 kilo „ | 0.0142 | 0.1728 | 1.985 | 10.9 „ |
| 6½ kilo „ 100 kilo „ | 0.00728 | 0.0778 | 0.875 | 11.2 25-8-36 |
| 12½ kilo „ 100 kilo „ | 0.01368 | 0.1425 | 1.542 | 10.8 „ |
| 25 kilo „ 100 kilo „ | 0.01336 | 0.1724 | 1.984 | 11.5 „ |
| 6½ kilo „ 100 kilo „ | 0.00688 | 0.0781 | 0.8565 | 10.9 19-10-36 |
| 12½ kilo „ 100 kilo „ | 0.01198 | 0.1431 | 1.5321 | 10.9 „ |
| 25 kilo „ 100 kilo „ | 0.01252 | 0.1732 | 1.978 | 11.3 „ |

Our work on nitrogen transformations in soil has been briefly summarised in 'Nature' (1936) in the following words :—

'MOLASSES, NITROGEN FIXATION AND LAND RECLAMATION.'

' In his presidential address to the United Provinces Academy of Sciences, India, on December 19, 1935, Prof. N. R. Dhar gave a general account of the work carried out by himself and his collaborators on nitrogen transformations in soil. Prof. Dhar leads the school of thought which believes that nitrification in soils and nitrogen fixation from the atmosphere are, especially in the tropics, photochemical at least as much as bacterial actions. Prof. Dhar has produced strong evidence in support of his theories, and the question appears now to have reached the stage at which the protagonists of bacterial and photochemical nitrification respectively are unwilling to admit any evidence which might shatter their beliefs.

' Meanwhile, other soil workers will be wise to keep an open mind on the matter, for the philosophical implications of recognising that light plays a part in soils analogous to photosynthesis in the vegetable kingdom are at least as important as the practical possibilities of utilising that knowledge for the enrichment of the soil. Given sufficient facts, their practical application does not necessarily depend on their correct interpretation. The practical facts of Prof. Dhar's researches are that Indian soils are generally deficient in nitrogen, that more than half a million tons of molasses from the sugar industry are annually wasted in India, and that the application of molasses to the soil can double and may treble the soil nitrogen content, with a consequent large increase in crop yield.

' Molasses contains about 70 per cent. of carbohydrates and small quantities of nitrogen, phosphorus, potash, etc., these quantities, however, being much too small to account for the observed manurial effect. According to Prof. Dhar, the energy set free in the oxidation of the sugars in molasses is utilised, either bacterially or photochemically, in promoting nitrogen fixation and nitrification. Whatever the nature of the process, Dhar has produced indisputable evidence of increases in available soil nitrogen and crop yields following the application of molasses. Under temperate conditions, the converse result would be expected, as it is well known that the addition of carbohydrate-rich material to soil tends to reduce the amount of nitrogen available to plants, the nitrogen becoming fixed as microbial protoplasm or as humus. An essential difference, however, between temperate and tropical soil requirements

is that, whereas in temperate regions the limiting factor to crop growth is often the slowness, in the tropics it is the rapidity with which soil nitrogen is made available to plants, soluble nitrates being formed and leached from the soil before they can be absorbed by the crop. The general effect of molasses on the soil should be the same everywhere, but only in the tropics will its 'braking' effect on the mobilisation of soil nitrogen be a positive advantage to the cultivator, and only in the tropics will its stimulation of atmospheric nitrogen fixation, whether bacterial or photochemical, be appreciable, since temperate regions lack the heat necessary for bacterial and the light for photochemical stimulation.

'For these reasons, the potentialities of carbohydrate manuring—of which molasses manuring is an example—have perhaps been overlooked by agriculturists. If Prof. Dhar can substantiate his claims, he may effect a revolution in agriculture in India, where the supply of the ordinary organic manures is far below the demand. Prof. Dhar suggests that a most valuable use can be made of molasses in reclaiming alkaline land. The acids produced in the decomposition of molasses neutralise the alkalis, and at the same time and contrary to experience when land is relaimed with gypsum or sulphur, soil nitrogen is increased.'

'A period of about four years is usually necessary to reclaim alkali land with gypsum, whereas with molasses applied at a rate of 30-40 tons per acre, good crops can be grown within six months. It is not stated whether such reclamations have been found permanent—in view of the oxidisability of the neutralising acids, this is open to doubt—but the method obviously merits further study. There are four million acres of infertile alkali land in India, and irrigation practices are increasing the area. The economic reclamation of these lands is one of the country's greatest agricultural problems, to the solution of which Prof. Dhar's work is pointing the way.' *Nature*, April 11, p. 629, 1936.

SUMMARY.

- (1) When 20 tons of molasses containing 60 percent carbohydrates are added per acre of normal soil, which is turned over once every month, 493 lbs. of nitrogen are fixed. Using 40 tons, 605 lbs. of nitrogen are fixed; whilst with 3 tons and 10 tons of molasses per acre, the nitrogen fixations are 112 lbs. and 270 lbs. respectively. Carbohydrate manuring in tropical countries appears to be better than symbiotic nitrogen fixation, which adds 50—100 lbs. of nitrogen per acre.

(2). The available nitrogen (sum of ammoniacal and nitric nitrogen) of the heavily molassed plots is as high as 16—17 per cent of the total nitrogen before the rains, whilst after heavy rains it is 11 per cent.

(3) Marked increase of crop yield has been observed in the molassed fields.

(4) No decrease of available nitrogen is observed when molasses, carbohydrates, glycerol etc. are added to the soil, which is exposed to air and light.

(5) The Azotobacter count of the soil exposed to sunlight is always less than that kept in the dark or covered with wooden planks, whereas the nitrogen fixation is greater in the exposed soil than that in the dark or covered.

(6) The total carbon of the soil exposed is always less than that of the dark, showing thereby that sunlight enhances the oxidation of the energy-rich substances and also causes greater nitrogen fixation. In light the nitrogen fixation is more efficient than in the dark, as the nitrogen fixed per gram of energy material oxidized in sunlight is practically double that in the dark. Sunlight appears to be utilized in nitrogen fixation as in photosynthesis. This phenomenon has been observed with many carbohydrates and glycerol added to soil in dishes or fields and seems to be a general one. Considerable amounts of nitrogen fixation have been observed when soil mixed with cellulosic materials like paper, green and dry leaves, sawdust, etc. are exposed to air and light. There is considerable decrease of the carbon.

(7) Cowdung, which is used as a manure for its nitrogen content, has been found to be able to fix considerable amounts of nitrogen from the air when mixed with soil and exposed to air and light. The amount of nitrogen fixation is much greater in the fields receiving sunlight than in those covered with wooden planks. It is clear, therefore, that the cellulose, pentosans, lignin etc. are oxidized on the surface liberating energy necessary for nitrogen fixation. With these substances also, the nitrogen fixation is enhanced by sunlight, which is utilized.

(8) Butter, Ghee (clarified butter), sodium tartrate, citrate, oleate, palmitate, stearate etc. when mixed with soil and exposed to air and light are oxidized on the soil surface and cause nitrogen fixation.

(9) As carbohydrates, fats, cellulose, lignin etc. are readily oxidized on the soil surface and cause nitrogen fixation, plant leaves, residues etc. should be

added to the fields before the rains, instead of composting them, because in the former case, not only the nitrogen contained in the plant materials are added to the soil but considerable amount of nitrogen is also fixed on soil surface.

(10) Our experiments (in progress) show that cellulosic materials mixed with sterile soil or ferrous hydroxide can be oxidized by air in presence of sun light.

(11) Unmanured fields in temperate countries produce decreasing crop yield; whilst in India it is believed that the soil can maintain its fertility for an indefinitely long time. Our results with field trials show no decrease in total nitrogen even after harvesting of rice. This behaviour is due to the simultaneous fixation of nitrogen caused by the oxidation of the plant residue and this is more prominent in tropical countries than in temperate ones.

12. It has been observed that the maximum fixation (largest amount of ammonia formation) takes place at about 35° , which is, therefore, the optimum temperature for Azotobacter isolated from the garden soil at Allahabad as against 28° obtained in temperate countries. There is hardly any ammonia formation at 10° , on the one hand and at 60° , on the other.

The optimum temperature for bacterial nitrification in tropical countries is 35° as against 25° in temperate climates.

13. Experimental results *in vitro* show that ammonium sulphate mixed with sterilised and unsterilised soils undergoes nitrification and amino acids added to soil or other catalytic surfaces are oxidised to ammonium salts to a greater extent in sunlight than in the dark.

Similarly dilute sodium or potassium nitrite solutions are readily oxidised to nitrate when exposed to sunlight. Hence it has been concluded that the whole process of nitrification is accelerated by sunlight.

14. The amounts of available nitrogen varies from 10 to 47.7% of the total nitrogen in soils collected from different parts of India, whilst in English soils it is only one per cent of the total nitrogen.

15. The carbon-nitrogen ratio in soils does not seem to be controlled by the energy requirements of the micro-organisms as advocated by Doryland but appears to be regulated by the ease with which proteins, amino-acids, ammonium salts, etc., are oxidised by air aided by bacteria, inductors, catalysts and light in presence of carbonaceous substances under different conditions and the oxidations taking place in the soil seem to be guided by the same laws, which rule animal metabolism,

16. The carbon-nitrogen ratio in soils rises with increase of the soil temperature.

17. Marked loss of nitrogen in the gaseous state is observed when nitrogenous compounds are added to soil in which the conditions are favourable for oxidation by aeration. This loss of nitrogen is high, when the amounts of nitrogenous manure added is large and can readily exceed the amounts of nitrogen required by crops.

18. When manures are composted in aerobic conditions there is greater loss of nitrogen than under anaerobic conditions. This type of nitrogen loss is chiefly due to the formation and decomposition of ammonium nitrite and nitrous acid from the nitrification of the nitrogenous substances and in the reduction of nitrate by organic substances.

19. The decompositions of ammonium nitrite, which can take place in the dark at temperatures from 20° upwards are accelerated by sunlight.

20. Field trials show that molasses, leaves, cowdung etc., markedly retard the nitrification of ammonium sulphate and decrease this type of nitrogen loss. Moreover when the amounts of ammonium salts added to the soil are not large, there is appreciable nitrogen fixation in presence of molasses. This nitrogen fixation cannot be explained from the bacterial view point.

21. Exposure to sunlight causes greater nitrification and nitrogen loss when ammonium sulphate is added to soil in fields.

22. Organic manures like molasses, leaves and cellulosic materials, green manures, cow dung, oil cakes, etc., when added to the soil not only increase the moisture retention capacity and improve the soil tilth but also conserve the soil nitrogen and adds nitrogen to the soil by fixation of the nitrogen of the air. Hence fields manured by cow dung and other organic manures contain more total nitrogen than fields manured by artificials. This appears to be the main function of organic manures.

(23) Results obtained with soil containing molasses and oil cakes show that there is considerable nitrogen fixation even in presence of the nitrogen in the oil cakes. In the absence of molasses, soil containing oil cakes, loses nitrogen due to aerobic denitrification. Similarly in fields containing ammonium sulphate and molasses, there is appreciable nitrogen fixation.

(24) Nitrogen fixation has been observed with mixtures of molasses and oil cakes added to soil with a carbon-nitrogen ratio as low as 5·05. Similarly

with a mixture of ammonium sulphate and molasses, nitrogen fixation has been obtained with a carbon-nitrogen ratio 7·7 and more ; with ratios smaller than the above there is nitrogen loss.

(25) These observations cannot be explained from the bacterial view point of nitrogen fixation and the significance of the carbon-nitrogen ratio, but follow from the photochemical and catalytic standpoint of the soil oxidation reactions.

(26) Pressmud, which is available in large quantities in sugar factories, containing calcium compounds, carbohydrates and nitrogenous substances, has been found to be an excellent reclaiming agent for alkaline soils, as the chief defects of alkali soils are remedied by the addition of pressmud. Mixtures of molasses and pressmud can also reclaim alkali soils.

(27) Oil cakes containing nitrogen compounds, oils, cellulosic materials etc. also remedy the defects of alkali soils and can reclaim them.

(28) Using one ton of molasses per acre, the Mysore Government obtained 1200-1800 lbs. of rice grains per acre of reclaimed alkali land, where the crop failed completely in previous years. Very bad alkali fields have also been reclaimed and excellent rice crop has been obtained at Soraon (near Allahabad), Una (Oudh), Cawnpore, Shahjahanpur U. P. and in Behar, using 3 to 10 tons of molasses per acre.

(29) Washing away of a normal soil by rain water or even good irrigation water removes more calcium than sodium and hence this leads to the formation of alkali soils from normal ones.

(30) Experiments show that on the addition of molasses and pressmud, the nitrogen and carbon contents of the reclaimed lands come up to the normal level or more. Hence these reclaiming agents are superior to gypsum and powdered sulphur, which do not add nitrogen and carbon to the soil.

I am greatly indebted to Messrs S. K. Mukerji, M. Sc., E. V. Seshacharyulu, M. Sc., S. P. Tandon, M. Sc., and N. N. Biswas M. Sc. for carrying on the experiments discussed in this address.

ADDRESS DELIVERED BY LT.-COL. R. S. WEIR, M.A., B.Sc.,

I.E.S., M.L.C., DIRECTOR OF PUBLIC INSTRUCTION,

UNITED PROVINCES, AT THE SIXTH ANNUAL MEETING

OF THE NATIONAL ACADEMY OF SCIENCES, INDIA,

on the 15th January, 1937.

Ladies and gentlemen,

I deem it an honour to be asked to preside at this meeting of the National Academy of Sciences, India. If your Academy is young it is vigorous and like the infant Hercules has given proof of its activity and ability to defend itself. Not only I but I believe the Government of these provinces also are proud of this infant in our midst and although times are lean we look forward to the days when we may be able to give to the Academy support more consistent with its increasing vigour. It requires little consideration to defend the subsidising of a body like the Academy. Its activities have been many sided and the quality of the papers submitted has been high. It has been a stimulus to study and has brought together science men from all over India. It has kept before the public the work that is done in the Universities.

The functions of a University have been discussed till nothing remains to be said on this head. Universities are regarded as great repositories of knowledge and possibly one might bear in mind here the remark of the head of a famous American University, who said that there could be no doubt that the students came to the University filled with all the knowledge that the schools could pump into them; likewise it was equally well known that the students took nothing away; therefore the Universities must be great store houses of knowledge.

In his famous book on Education, Spencer sets before him the problem "What Knowledge is of most worth" and he answers it in a word 'Science'. He says "We conclude, then, that for discipline, as well as for guidance, Science is of the chiefest value. In all its effects, learning the meaning of things is better than learning the meaning of words. This is the verdict on all the counts.

Alike for the most perfect production and highest enjoyment of art in all its forms, the needful preparation is Science. And for the purposes of discipline—intellectual, moral, religious the most efficient study is once more—Science”.

We here today are a living testimony to the wisdom of this pronouncement. Each of us in some sphere stands for the development of science. But I have today to make some remarks on concepts of Science and the work in Science that strike me as calling for the attention of scientific men. Literature has produced a caricature of the man of Science, pale, bespectacled, bald and domed as to the cranium, he performs prodigies of deduction and is yet as simple as a child. Our daily papers carry on every page advertisements based on a very casual acquaintance with Science.

Prorridge is full of vitamins. Cod liver oil is irradiated. Tooth paste is assessed on its germicidal value, while hormones, ductless glands and psycho analysis are familiar features in every page. The Universities get larger and larger, their machinery is overloaded with third class students. Their fields of instruction are widened. Their libraries grow larger year by year. There is much running to and fro. Convocations, committees, addresses and debates crowd in upon our daily work. But few seem to have time to ask what all the fuss is about, why they are attending the University or to what end all this accumulation of knowledge is directed.

The attention of the public has been very forcibly directed of late to the absence of a plan in our educational system. In these provinces the expenditure from public funds on secondary and collegiate education is twice the expenditure on primary education. In consequence the market is overloaded with educated young men, qualified in philosophy and economics while the illiterate peasant toils humbly in his fields ignorant of anything beyond his village. A similar state of affairs seems to exist within the universities in a lack of plan of coordinated effort. There is no real lack of funds although Universities are always pleading poverty and in the budget ample provision is found for scholarships and research, but in the direction of this provision things are not so satisfactory. There is no dearth of researchers. No lack of effort. But the result is largely an accumulation of educational lumber. The shelves of the libraries groan with papers that are of no use to anybody. The desire to see something in print rather than the desire to do something worth doing, something considered as a contribution to a planned system, is

responsible for this cluttering up of our laboratories with much useless material.

Further I have no doubt that these research scholarships are a great temptation to young men who see no immediate opening in the world. Here in a sheltered haven the young man may spend two years contemplating the stormy seas outside the University walls and wondering to what use he can put his fine academic accomplishment in such wild waters. The real spirit of the researcher is absent. Do these young men of today undergo difficulties and hardships, devise experiments, live dangerously, sacrifice anything or lack any comfort? How many of them have heard of Bernard Palissy burning his chairs, his fence, his floor to keep going the furnace in his search for the potter's glaze. How many of them have read of Heinrich Schlieman, son of a poor German pastor, studying ancient languages as a grocer's assistant, a cabin boy sailing round the world and a book-keeper so that ultimately he might excavate Troy and Mycenae and determine history. Or of Pasteur, son of a tanner and dubbed "mediocre" in his Chemistry Examination going on with his experiments in the face of opposition from the savants of his time. Of Livingstone in the wilds of Africa, of Faraday, the son of a blacksmith, listening to Davy's lectures, of George Stephenson, son of a foreman at a colliery, unlettered and earning a shilling a day destined by his constant effort to drive the first engine and to establish the railway and the locomotive as a power in the world. Instead, the young man flushed with the pride of his M.A., or M. Sc., potters around with some miserable question of whether the Huns were white, yellow or blue, peers through the microscope at the entrails of some inoffensive insect, boils up some new compound of methyl ethyl para hydroxy anthroquinone, performs a little juggling with a triple integration, proves that Kant could not have been serious when he wrote his Kritik of Pure Reason, and then unloads this stuff on a long suffering public. This is not real research and work of this type should be brought under control by the Academy. There is plenty of honest work to be done, and the time and money spent on the present sterile research should be turned to better use.

To what end should research be directed. Spencer has already said that Scientific knowledge is preeminently of the greatest value to mankind and I for one agree with him. But the Scientific knowledge has to be useful knowledge and not the sterile futile stuff that is piling up all over the world under the name research. An explorer can excavate a site and turn up merely a few copper coins, a broken urn, a rusted hilt. Is there any justification for the

tomes that can be written over these things ? The deciphering of the cuneiform writings at Behistun by Sir Henry Rawlinson 1835-45 or the building up from the Rosetta stone by Champollion in 1822-30 of the heroglyphic dictionary is a feat of the first order but the stirring up of a furore over some small find is unpardonable in a man of Science. Here is where the Academy of Science should set its face against the pot hunter the man who wants to achieve fame on the minimum of solid work. Let the Academy show its approval of those who quietly and unostentatiously add their contribution of knowledge. Let it be frigid to the charlatan, the chatter-box, the politico-scientist. In other words, let the Academy show its approval to honest work and let it definitely discourage the attempt to climb into notice by the publication of cheap imitations of research.

And amid the numerous causes which the Academy may help let the foremost be that of serving mankind in India. To those who labour towards improving the conditions of life here in India let the Academy lend its full support. I am familiar with Dr. Dhar's research into the use of molasses in agriculture. I was in the Council when the bill was passed dealing with the pink boll worm. But I wonder what prevents the development of the manufacture of power-alcohol in India. I want to know what can be done to improve our roads, the tar, the materials, the construction, whether remedies can be found for the diseases that cut down so many of our men, what steps can be taken to render efficient the working of our local boards. There is ample room for research in this field—the service of the community and the field is of far greater importance than those in which many of our young researchers are at present working. It is far more important to keep going a glass factory, a sugar cane factory, as I saw last week at Fyzabad or a leather work than it is to play about in a University laboratory or library writing a thesis on problems of civil administration in some far off time or place or concocting some new and useless chemical compound. Said Swift "The man who can make two blades of grass grow where formerly there was but one is of more value than all the philosophers". And despite all the Sarcasm about bread and butter philosophy and much hot air about ideals and spiritual vision Swift was right. It is the duty of every one of us to remember that we are carried on the back of the peasant. We may administer, write, boil, bake, brew, teach or learn, work or idle but ultimately we must eat and in eating we depend on the peasant. Society exists by the labour of the working man. Then let our labours be directed to securing for the peasant, the universal

provider, a better home, a better life, a better return for his labour. Ignorant, poor, conservative, humble and content, he is yet the most important man in our midst. And if research is to be of value it must of value to the peasant. His needs should be the first to receive the consideration of the Academy, his wants should feature on the agenda today.

There was a time in English literature when it was considered beneath the dignity of writers to write about the poor. That age of artificial ideals is long gone by. It was succeeded by an age of realism which went to the opposite extreme. Here in the Academy of Science I hope that you may strike a happy medium and remembering our debt to agriculture and the country side we may develop our knowledge so as to serve the entire community.

What I have said applies to all of us. We must get to work. This was the motto of Louis Pasteur—and every young scientist should know the life and work of this great man. Ever he would say to his staff when an experiment was successfully completed, "If faut traveller" Work and not play, filling in the time, unplanned activity, dilettante science. Yet I learn that it is proposed in some quarters to limit the hours of teaching work of professors, of lecturers and of readers. One of my correspondents works it out that these rules would limit the teaching of a professor to about $1\frac{1}{4}$ hours per day. Gentlemen, such regulations cast great discredit on the profession. They can be construed as exhibiting the worst features of trade unionism at its lowest ebb. As my correspondent says "Does any one believe that the work of a Professor is more arduous than that of a judge or the D. P. I. who has to work long hours after he has left his court or his office"? Regulations of this type do much to foster the common belief—and I shall be frank with you—that University posts are largely sinecures. And from the Universities this spirit of "Ca cauny", this acceptance of limitation of labour, of insistence on free periods has spread to and has corrupted the entire educational system. I speak not only of India but of all countries. There is too much of the spirit of the lotus eater in education. "At length they came into a land where it seemed always afternoon." Let me recall to you what your forefathers did in education. To start with, consider the Admirable Crichton who in Paris in 1580 held a dispute on any subject and in twelve languages and next day won a tilting match, at the Louvre. Of thirty years before him Lady Jane Grey, great grand daughter of Henry VII, remarkable no less for her accomplishments than for her misfortunes and destined to die on the scaffold at the age of 17. She excelled in needle-work and in music. While still

very young she had mastered so as to speak and write with accuracy, Greek, Latin, French and Italian and had some knowledge of Hebrew Chaldee and Arabic. The love of learning was her solace and she found a refuge from domestic unhappiness in Demosthenes and Plato. Will those kind souls who shed tears over the overloading of the curriculum consider such cases? Let me recite to you the regime in the school at Kingswood where in 1750 the Rev. John Wesley taught the children of methodists. The children admitted to the school were to be between the ages of six and twelve and they were taught reading, writing, Arithmetic, English, French, Latin, Greek, Hebrew, History, Geography, Thetoric, Logic, Ethics, Geometry, Algebra, Physics, and Music. They had to rise at four and to attend service after private prayers at five every morning. Breakfast was at six and lessons began at seven continuing for four hours. There was a break at eleven for "working or walking." Dinner was at twelve after which there was a short spell of work in the garden, or singing. From one to five, lessons were continued. Between five to six there was time for private devotions."

I have given this long description to convince you that you and I, the teachers in schools and the pupils there, are capable of effort far beyond those which we now attempt. There has been for many years an insidious movement towards learning less and less. It becomes History or Geography instead of History and Geography, Urdu or Hindi instead of Urdu and Hindi. Soon it will be Physics or Chemistry. And ever the plea is that the child is overburdened. Gentlemen, the child is not overburdened. He is not well taught.

Let me however revert to my original theme which was the accumulation of useless knowledge. The educational authorities in England have revised their syllabus. No longer do children need to learn how to extract cube roots of enormous numbers or find when leaky baths will fill. They are not required to know the counties of Scotland or the population of Iceland. They are expected to learn such things as will be of use to them in their life. This principle should be extended to higher studies. It would do much good if once a month the staff of the Universities were made to spend a Sunday—not a working day—in an ordinary village, to see the conditions of life, the huts with leaking roofs, the dirty lanes, the illiterate children, the unsanitary wells, the country carts still in the form familiar when Alexander met Porus, the lack of any convenience or comfort in life. Yet from such villages come boys whose heads are filled in our Universities with higher mathematics, abstruse philosophy, and recondite theorems. Gentlemen, this is all wrong. I do not ask Professors

to follow Ruskin and start model shops for the sale of tea, found hostels for poor students or set their pupils to work to repair country road (though the roads round Allahabad could do with some repair) but I do ask them ever to bear in mind that pathetic mass of illiterate and humble people to whom University studies are moonshine and that equally menacing figure the unemployed graduate who wanders round with his degree offering his services and knowledge and finds no takers. You will remember how in his travels Gulliver came to the flying island of Laputa where the philosophers had each in attendance a slave gently to tap him on the head and recall him to his surroundings when he wandered in his musings. Today I take on myself the duty of the slave and ask you to look beyond the walls of the lecture room and of the laboratory and remember the millions who will never hear or see you.

And let me conclude by a quotation from Louis Pasteur that great man who is to my mind the true type of research student. I quote from his address to the Assembly which had gathered to do him honour after the establishment of the epoch making treatment of rabies :—

“Young men, have confidence in those powerful and safe methods, of which we do not yet know all the secrets. And, whatever your career may be, do not let yourselves become tainted by a deprecating and barren scepticism, do not let yourselves be discouraged by the sadness of certain hours which pass over nations. Live in the serene peace of laboratories and libraries. Say to yourselves first ‘What have I done for my instruction?’ And as you gradually advance, ‘What have I done for my country?’ until the time comes when you may have the immense happiness of thinking that you have contributed in some way to the progress and to the good of humanity. But, whether our efforts are or not favoured by life, let us be able to say, when we come near the great goal, ‘I have done what I could.’

ADDRESS DELIVERED BY SIR JOHN RUSSELL, F. R. S., DIRECTOR
OF Rothamsted Experiment Station

AT THE SIXTH ANNUAL MEETING OF THE NATIONAL ACADEMY OF SCIENCES,

INDIA, ALLAHABAD.

On the 15th January, 1937.

Very many years ago it would have been necessary to apologise to a scientific audience such as the present for giving an address on applied subject. Now, however, it is recognised that applied science and pure science have much in common; the method is the same and their objects differ but little; both serve for the enrichment of life—the one on its intellectual, the other on its material side.

Advances in agricultural science have mainly been effected as a result of seeking the solution of a practical problem. Boussingault's original experiments were designed to improve his farming. Lawes' discovery of artificial fertilizers was to increase the output from his land. Pasteur's investigations began by trying to avoid certain "diseases" of beer. The original discovery of nitrification resulted from the attempts of Schloesing and Muntz to purify the sewage of Paris. In India, Barber's investigations on sugarcane, which forms the foundation of a great deal which is now being done, started from his attempts to improve the yield of sugarcane. The work done on wheat by Dr. and Mrs. Howard had the same practical purpose in view. Mr. Hutchinson's work at Indore on cotton and juar began with purely practical issues but before long led to the enunciation of an important hypothesis in regard to the gene. Although purely laboratory work can do much to explain the processes in detail, the best inspiration always comes from the field and this remains the best source of new material. This is particularly true of India and in going round the various districts I have been struck by the large number of field problems that still await solution.

There are three fields of scientific activity in connection with agriculture.—(1) purely scientific work which is done apart from any practical application, though it has often begun with attempts to explain some process or field observation. The best known example is concerned with the so-called nitrogen cycle in the soil, an important chain of processes vital to the whole realm of crop production. This type of work is best done in association with University teaching so that the Professor can have the help of competent students who will gain directly by being associated with investigations into natural phenomena.

The practical applications are best studied at research stations and experimental farms. These fall into two groups concerned respectively with (a) specialised crops grown on a large scale as raw material for factories or industry, e. g. cotton, sugarcane, tea : (b) crops grown as human or animal food—wheat, rice, jowar etc. For the factory crops the problems are difficult but the organisation of research work is relatively simple. The buyers know exactly what they want and the business of the agriculturists is to provide this. It is not for the agriculturist to lay down standards but to find out what the buyer requires and to discover the means of supplying his needs. A good example is furnished by the Indian work on cotton at the laboratory at Matunga near Bombay organised by the Indian Cotton Committee on which the millowners are well represented. The workers there try to reduce mill-owners' requirements to precise scientific terms. They are in close touch with the agriculturists and are able to explain to the agriculturists exactly what they are expected to provide. The cotton investigators at Indore, Coimbatore and elsewhere are provided with a clear information as to the problems they are to study.

Agriculturists have been remarkably successful in solving problems put to them when the problems have been sufficiently definite. In the production of cotton for example, agriculturists have succeeded in building up plants almost to the millowners' specifications and they have succeeded in combining good milling quality with high yields, thus achieving the almost impossible feat of satisfying both the producer and the consumer. Sugarcane also has been a source of many triumphs for agricultural science. The methods introduced by Dr. Barber and developed by Rao Bahadur Venkataraman and by the staffs of Sugarcane Research Stations at Muzaffarnagar, Karnal, Shahjahanpur, Coimbatore and elsewhere, have succeeded in producing canes that combine the qualities required by the factory; a high percentage of

sucrose, a satisfactory purity of juice and a suitable fibre content, with qualities required by the cultivator, such as high yield, resistance to some of the worst of the insects and fungus pests and resistance to the ill effects of water-logging. The investigators are now engaged in the difficult problem of trying to secure a wider spread in the time of harvesting so that the factories will be able to work for a greater number of days than at present so that the cultivator may have his task evenly distributed over the whole year.

Tea growing also affords notable examples of the achievements of agricultural science; the work done by Dr. Mann, and continued by Mr. Carpenter and the staff of the Indian Tea Association, has given Indian tea an assured place in the world market, so that in England it is more widely drunk than tea from any other country. The essential thing in all this technical work is that the agriculturists and the expert users should collaborate. The agriculturist may find it convenient to set up quality tests in his own laboratory but he must fully realise that these have no value whatsoever unless the expert user is prepared to accept the results. Normally he is not, and the user likes to apply his own tests. This applies with particular force to barley. A certain amount of Indian barley is sent to England for malting, and as Chairman of the Barley Committee of the Institute of Brewing I received reports on many of the samples. In the main the quality is not good and although it would be possible to improve it by studying diligently the market requirements and taking drastic steps to ensure good quality, yet I am very doubtful whether India ought to be exporting so valuable a food grain. Looking down the dietaries of the Indian villages so far as I have been able to obtain them, they seem, as a rule, to be short of protein. Now the Indian barley contains more protein than usual and indeed its high protein content is one of its disadvantages on the world market, for a barley buyer tends to prefer barleys of low nitrogen content. Its high nitrogen content is probably an advantage so far as food is concerned. There is also a demand for malt foods in India for infants and invalids, and Indian barley might be malted locally to supply this demand; for this purpose its high protein content would probably be no disadvantage; indeed I should not be at all surprised if medical opinion were in favour of a high protein content for this special purpose. Further the residues from any malt extract prepared locally would constitute a valuable cattle food for milch animals. The demand for malt foods however is probably not very great and the greater part of the barley could find good use as an ingredient in the peasants' dietary.

Leaving now these products grown for factories or for industry and passing on to the second group of agricultural products, those grown for human food, the problem is much more difficult and very much less definite. In regard to wheat the position is fairly clear. In the western countries people require a loaf of a certain texture and consistency, and Millers Research Associations have proceeded to show what characteristics the wheat must possess in order to impart those qualities to the loaf. The problem in short has become exactly like that of any other factory product; the expert user has laid down certain standards, which the agriculturist has learnt to satisfy. Canada and the United States have learnt precisely how to grow wheat required for the Western market and Canadian wheat usually obtains top prices. The Howards at Pusa also produced a wheat in the same class and no doubt others could be produced also.

Apart from the Western market, however, these standards have no particular value. It is not all clear that the wheat preferred in the Western market is of higher nutritive value than that which obtains a lower price. The standards have no relation whatever to human nutrition but only to texture and appearance of the loaf. They need not therefore be accepted in India.

One of the most striking features about the dietary of the Indian villager is its monotony. The various provinces have their preferences; in Bengal for example 98 per cent of the area under all grain crops is devoted to rice; in Bombay Presidency a very large proportion, nearly 70 per cent. of the area is in Jowar and Bajra. In Mysore about 65 per cent. is in another millet, Ragi. So far agriculturists have confined their efforts to attempts to increase the production, largely by looking for new varieties, and by trying to improve the cultural methods. In this they have been fairly successful. Consideration of quality have hardly entered into the investigation and this is quite a sound procedure at any rate in the initial stages. All experience shows that the composition of grain is not easily altered either by cultivation or manuring. It is, however, largely dependent on the soil and climate. Seeing then that the cultivator is hardly in a position to alter these, unless he can irrigate his land, it is obviously better for him to obtain the largest yield possible and to accept whatever quality may be associated with it.

Considerable improvements in the cropping scheme could, however, be effected if the agricultural and the medical authorities could work together. Assuming for example that in a given region the main item in the peasants'

dietary is rice, what other foods should be grown in order that the peasant may have a properly balanced dietary? If the medical authorities could give alternative lists the agriculturists could show how to fit these foods into the cropping scheme and they could select from the medical lists the crops that would enable peasants to obtain a better diet than at present. One could hope, to achieve the same kind of success in the production of human food as has been attained in the production of technical crops.

The great need of Indian agriculture at present is increased production of all of these food crops. A good deal has already been achieved by the introduction of new varieties but it is doubtful whether much more can be done without increasing the productiveness of the land. Improved varieties can extract whatever fertility is there, but they cannot add to the fertility. Therefore, it is necessary to take some definite steps to do this.

The same problem was presented to British agriculturists about 100 years ago. Up till that time there had been very considerable similarities between Indian agriculture and English agriculture. In both cases the chief product was grain for human consumption, and two definite cropping seasons were recognised—winter cropping and summer cropping. The holdings were small and scattered just as in India; the ploughs were of wood; and most of the farm work was done by bullocks. The animals had no crops grown expressly for them; they had to live on straw and on such wild herbage as they could pick up during their grazing.

The similarity between Indian and old English agriculture was so close as to suggest a common origin for the two systems, and if one may use a word which is now acquiring considerable political significance in Europe, one would surmise that both systems were Aryan in origin. The English cultivator obtained about 7-8 maunds of grain per acre as a rule, though in bad seasons he would get much less and the crops would be liable to disease. The present yields are about 25 maunds per acre on the average, but 40 maunds on the good farms. In 150 years the yields have been pushed up to 5 or 6 times their older level.

The most important single factor was the improvement of the food-supply for the animals; this was done by putting half the land into fodder crops and only half into grain crops for human consumption. The additional fodder meant that the animals were much better, and were able to do more work. They gave much more milk and meat and much more farmyard manure. This

when applied to the land increased its productiveness. One of the most popular fodder crops—clover-had the same effect. The other fodder crops gave opportunities for cultivating the land which much improved its condition. There was an old saying that bigger crops gave more animals, more animals gave more manure, and more manure gave bigger crops. The cycle of improvement, once started went on increasing. The starting position was very similar in India and in England ; both had an agricultural system which produced mostly grain for human consumption but very little animal food. The present position, however, is very widely different ; in India less than 5 per cent. of the land is in fodder crops whilst in England some 80% of the land is devoted to crops for animal consumption, and this gives quantities of milk, eggs and other animal products to vary and enrich the national dietary. If it should ever be possible to blend animal husbandry with crop production in India, one might expect a very marked improvement in crop production here also, in this case the need would be not for more animals but for better animals, but these cannot be produced until the supply of food for them is assured; one thing is known with certainty : and that is that animals cannot be improved unless they have sufficient to eat. It may be impossible to solve the problem this way in India : on that point I am not yet prepared to express an opinion.

Another very important factor, in the improvement of British agriculture is the presence in the village of the squire, an educated landowner who is interested in his land and his tenants, in the farmers and the workers, and is ready to try new methods once he is satisfied that they are likely to be useful. In many villages also there are enterprising farmers keenly interested in agriculture, and very anxious to improve it. Every district has its leaders in agricultural improvement and the advisory officers seek these men out and help them in every way possible by bringing to their notice improvements and developments likely to be useful. England has never had the problem of the absentee landowner ; the landowner practically always resides on his land and has recognised that he has a responsibility and a duty towards all the people that live on it. Of course all landlords have not lived up to the best traditions of their class, and they have not all practised the principles they profess.. But there have always been large numbers of them who quietly devoted their lives to the improvement of life in the village and the development of the local agriculture. During my journeys through India I have met occasionally examples of zemindars who also recognised their responsibilities to the land ; who lived in the village and endeavoured in every way possible to improve the

village life and raise the standard of agriculture. I have even come across one or two University graduates who settled down to a life of practical farming. But they are very few. If more men of this kind were available I am sure that Indian agriculture would benefit considerably. I sincerely trust that some of India's many graduates may think quite seriously of the possibilities of an agricultural career.

For the present, however, we have to think of other means of raising the productiveness of the land, for whether the dietary is adequate or not in point of vitamin and the mineral supplies, it is certainly insufficient in total quantity. An increase of 10 or 20 per cent, in the total production of food crops would add greatly to the food supply for the cultivator.

One of the most important factors limiting crop yield in India is the water supply for the plant and the relation between soil, the store-house of water for the plant, and the growth of crops requires full and detailed study. Fortunately methods of investigation are now becoming available with the development of colloid science, but this is a case where further progress in practical agriculture can hardly be expected till more progress has been made with this rather abstruse and apparently academic branch of chemistry and physics.

Many problems also arise in connection with the supply of plant food, particularly in regard to nitrogen about which Dr. Dhar has spoken this afternoon. The question whether the nitrogen is best applied in the organic or inorganic form awaits further investigation ; in one case composts and cow manure afford the vehicle, in the other case the commercial products—sulphate of ammonia, nitrate of soda etc. So much work has been done in India on the making of composts that it is important now to find out how effective they really are under different soil conditions, and having discovered their action, to try and explain and improve it.

A third group of problems arises in connection with the search for new varieties of crops which must go on unceasingly for there is no finality in crop improvement and it is certain that continued search will yield something better than is already used. The peasants' fields contain a wealth of material that has not yet been fully sorted out, and some stray head of juar or bajra may contain seed which, when multiplied, would enrich a province. Continued effort is necessary also to ensure better distribution of the seed among the peasants. Improvement can be in the direction of finding more productive varieties, or varieties that will produce the same yield but take less time about

it so that they occupy the ground for a shorter period and so leave the cultivator free to do something else with it. Varieties more resistant to disease and pests are also sought.

Another continuous search is for means of combating pests and diseases, for with improved means of transport these enemies of the cultivator travel almost as easily as his friends; if a pest appears in one part of the world it is only a matter of time before it spreads to all regions where the conditions allow to live. Constant watch is kept by plant pathologists, entomologists, mycologists and others, but constant work is necessary to discover means of avoiding the damage thus done.

Another direction in which further progress is necessary is in regard to the improvement of farm implements and of farm carts. Agricultural engineering was early developed in the United States; its purpose there was to save man power. In India the need is rather different. It is to save bullock power so that the cultivator need not keep so many animals for draught purposes as at present. If he could reduce his stock in this direction, he would be able to give the remaining animals more food and do get more work or more milk from them.

One of the greatest problems in Indian agriculture is to provide more food for the animals.

Again however it must be insisted that for the full development of Indian agriculture the services of the medical and health experts are needed in order to say what crops should be grown in each region to supplement the deficiencies of the dietary. Confronted with a definite problem of that sort the agriculturist can usually devise ways of solving it.

Agricultural improvement must be developed on a threefold foundation (1) definite knowledge gained as a result of precise scientific investigations; (2) applications of this knowledge worked out and carefully tested at the experimental stations; (3) interpretation and utilisation of the results in such a way that the cultivators in the villages can use them.

At the present time great interest is taken in rural development and village uplift, and it is a very hopeful sign that people in India are thinking about the villages. The surest basis for rural development is the improvement in the economic conditions of the village and this necessitates an increased output from the land. I have seen sufficient of Indian cultivators and their expert advisers and agricultural investigators to believe that considerable improvement can be effected.

EDUCATION MINISTER'S GOLD MEDAL

Lt. Col. R. S. Weir in giving away the Education Minister's Gold Medal to Dr. D. S. Kothari, reader in physics, University of Delhi, remarked as follows :—

The Council of the National Academy of Sciences, India, has decided to award the Hon'ble Education Minister's Gold Medal to Dr. D. S. Kothari, Reader in Physics, University of Delhi, for his important contributions on "STELLAR STRUCTURE."

Dr. Kothari is a brilliant ex-student of the Allahabad University by whom he was sent to Cambridge for higher studies in Physics, but his contributions in the subject began while he was on our staff. His numerous contributions to Astrophysics has won for him a very high place amongst the workers on the subject. His latest contribution on Pressure Ionisation has evoked spontaneous admiration from such a great authority as Sir Arthur Eddington who in course of a lecture at the Harvard Tercentenary made the following remarks : "I mentioned that we only gradually came to realize that ionisation could be produced by high pressure as well as by high temperature. I think the first man to state this explicitly was D. S. Kothari. Stimulated by some work of H. N. Russell, Kothari has made what I think is an extremely interesting application. The relation of ionization to pressure is a curious one ; for at low pressures we decrease the ionization by increasing the pressure ; but the ionization must have a minimum, for at high pressure the Fermi-Dirac complication steps in and the ionization ultimately increases with pressure. No one seems to have bothered much about this revised ionization law ; they have been content to recognize or I think rather to guess that in white dwarfs the ionization would be pretty high. Kothari, however, has treated it seriously and worked out the degree of ionization in various conditions, including comparatively small masses in which the pressure is relatively low and the ionization is not very high". Prof. Kothari's recent contributions on 'STRUCTURE OF PLANETS' which is a continuation of his work on 'STELLAR STRUCTURE', promises as, Prof. Milne thinks, to solve an outstanding problem in Astrophysics.

VOTE OF THANKS

Prof. M. N. Saha in proposing a vote of thanks to Sir John Russell remarked :—

The Rothamsted Experiment Station of which Sir John Russell is the Head, is a unique institution of its kind in the world. Founded nearly a hundred year ago by Sir John Bennet Lawes out of his private funds at a time when no body shared the belief that agricultnre would be benefited by the application of science, it has grown to a very useful institution and its services to the country is recognised by a substantial grant by the Government. The Rothamsted workers have made many contributions regarding the use of fertilizers and the necessity of studying the soil science, which are of highest value to agriculture in every country. The present Director Sir John Russell started life as a chemist and has enriched the agricultural science by many first class contributions. It is a matter of sincere gratification that the Government of India has thought it fit to seek his advice as many problems of India still await solution. He has been kind enough to give us the benefit of his experience by coming to the anniversary meeting of our Academy and describing to us part of his experiences in this country and giving very salutary advice regarding the necessity of scientific research in agriculture. We hope that the Government of India and the public will be immensely benefited by his advice. On behalf of the members of the Academy I request you to join me in proposing a hearty vote of thanks to Sir John Russell for kindly gracing this meeting by his presence.

SECOND VOTE OF THANKS BY DR. SAM HIGGINBOTTOM

Mr. Chairman, Ladies and gentlemen,

I have much pleasure in seconding a vote of thanks to Sir John Russell. But as the hour is late and our tea will be getting cold, I follow the example of Dr. Saha and say little. After such a stimulating, thought-provoking address there is much that I would like to say, but I must refrain. While I am on my feet however I just want to say for the benefit of some of those who are pessimists about things in Indian condition, that I am a confirmed optimist. Spencer has been quoted to-day. I believe he is the author of the statement that men finally go right not from any purposed desire to go right, but having exhausted every possible way of going wrong, there is no other way left but to go right.

VOTE OF THANKS BY PROF. A.C. BANERJI TO COL. WEIR

Ladies and Gentlemen,

I have great pleasure in proposing a hearty vote of thanks to Col. Weir for kindly coming and presiding over this afternoon's function. Col. Weir's interest in education is well known. He is successfully steering the course of educational progress in this province on its onward march.

We are getting Rs. 2000/- per year from Government. But this sum is inadequate and the emaciated Academy of Sciences needs porridge, cod-liver oil and other nutritious stuff for a vigorous growth. We shall be thankful to Col. Weir if with the spirit of a true scientist he makes researches in the finances of his Department and sees his way to give us a more substantial grant which will enable us to increase the efficiency and extend the usefulness of our Academy in various directions.

SECOND VOTE OF THANKS BY DR. D. R. BHATTACHARYA

Ladies and Gentlemen,

I have pleasure in associating myself with the vote of thanks proposed by Prof. A. C. Banerji. The D. P. I. and the Deputy Secretary to the Government has multifarious and very onerous duties to perform. It is a matter of gratification to us that he has found time to come to the University functions four times within the last thirtyfive days. He has very kindly promised help to the Athlectic Association, generous help to the Music Department, and I hope he will promise substantial help to the National Academy of Sciences, India. I second the proposal most heartily.

Prof. B. Sahni proposed a vote of thanks to Prof. N. R. Dhar, the retiring president, and Dr. P. L. Srivastava seconded it.

APPENDIX I

ABSTRACT OF THE PROCEEDINGS

The council resolved that the fellows of the U. P. Academy of Sciences as well as those of the National Institute of Sciences of India be nominated for election as Fellows of the National Academy of Sciences, India.

The council resolved that Prof K. N. Bahl, as additional Vice-President, and Prof. A. C. Banerji, as Additional member, be nominated for the council of National Institute of India for the year 1936 of behalf on National Academy of Sciences.

The council resolved to accept the recommendation of the editorial board that no paper exceeding five pages of printed matter should be published in the proceedings except with special permission of the council

The Council expressed its gratitude to the Government of the United Provinces for the grant to the Academy for the year 1936-1937 and to the Council of Agricultural Imperial Research for its grant of Rs. 500.

The following members were elected Fellows of the Academy in the Fellows Meeting held on April 20, 1936.

Physics and Meteorology

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|---------------------------------------|--------------|
| 1. Prof. M. N. Saha, F. R. S., | (Allahabad). |
| 2. Prof. Ch. Wali Mohammad, I. E. S., | (Lucknow). |
| 3. Prof. S. K. Banerji, D. Sc., | (Poona). |
| 4. Dr. C. W. B. Normand, D. Sc., | (Poona). |
| 5. Prof. D. M. Bose, Ph. D., | (Calcutta) |
| 6. Dr. D. S. Kothari, Ph.D., | (Delhi). |
| 7. Dr. S. S. Nehru, I. C. S., | (Mainpuri). |
| 8. Dr. N. K. Sethi, D.Sc., | (Agra). |
| 9. Prof. J. B. Seth, | (Lahore). |
| 10. Prof. F. N. Mowdawalla, | (Bangalore). |
| 11. Dr. K. P. Row, | (Waltair). |
| 12. Dr. I. Ramkrishna Rao, | (Waltair), |

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| 13. | Prof. Kamta Prasad, | (Patna). |
| 14. | Mr. G. Chattaerji, M.Sc., | (Agra). |
| 15. | Prof. Rudolf Samuel, Ph.D., | (Aligarh). |
| 16. | Dr. R. N. Ghosh, D.Sc., | (Allahabad). |
| 17. | Dr. P. K. Kichlu, D.Sc., | (Lahore). |
| 18. | Prof. B. B. Ray, D.Sc., | (Calcutta). |
| 19. | Dr. R. K. Asundi, Ph.D. | (Aligarh). |
| 20. | Dr. D. B. Deodhar, Ph.D., | (Lucknow). |
| 21. | Dr. A. K. Das, D.Sc., | (Calcutta). |
| 22. | Prof. Raja Ram, | (Kasauli). |
| 23. | Mr. Saligram Bhargava, M.Sc., | (Allahabad). |
| 24. | Dr. S. K. Pramanik, Ph.D., | (Karachi). |
| 25. | Dr. K. N. Mathur, D.Sc., | (Lucknow). |
| 26. | Dr. S. Ramchandra Rao, | (Annamalainagar). |
| 27. | Dr. N. K. Sur, D.Sc., | (Agra). |
| 28. | Dr. S. Dutt, D.Sc., | (Calcutta). |

Mathematics

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| 29. | The Hon'ble Sir Shah Muhammad Sulaiman, Kt., | (Allahabad). |
| 30. | Dr. R. P. Paranjpye, D.Sc., | (Lucknow). |
| 31. | Dr. Ziauddin Ahmad, | (Aligarh). |
| 32. | Prof. N. R. Sen, | (Calcutta). |
| 33. | Prof. A. C. Banerji, M.A., M.Sc., I.E.S., | (Allahabad). |
| 34. | Dr. Gorakh Prasad, D.Sc., | (Allahabad). |
| 35. | Dr. P. L. Srivastava, M.A., D.Phil., | (Allahabad). |
| 36. | Prof. P. C. Mahalanobis, I. E. S., | (Calcutta). |
| 37. | Dr. N. M. Basu, | (Dacca) |
| 38. | Dr. N. K. Bose, Ph.D., | (Lahore). |
| 39. | Dr. M. R. Siddiqui | (Hyderabad, Deccan). |
| 40. | Dr. Luxmi Narayan, D.Sc., | (Lucknow). |
| 41. | Dr. T. Vijagaraghavan, D.Phil., | (Dacca). |

42. Dr. B. N. Prasad, D.Sc., Ph.D., (Allahabad).
 43. Prof. V. V. Narlikar, (Benares.)
 44. Prof. J. A. Strang, M.A., (Lucknow).
 45. Mr. B. L. Gulatee, (Dehra Dun).
 46. Dr. J. Ghosh, Ph.D. (Caleutta).

Chemistry and Technology

47. Prof. N. R. Dhar, D.Sc., I. E. S., (Allahabad).
 48. Prof. P. S. MacMahon, M.Sc., F. I. C., (Lucknow).
 49. Dr. S. M. Sane, Ph.D., (Lucknow).
 50. Mr. R. C. Srivastava, (Cawnpore).
 51. Dr. Mata Prasad, D.Sc., (Bombay).
 52. Dr. M. Qureshi, Ph.D., (Hyderabad, Deccan).
 53. Dr. Sri Krishna, (Delhi).
 54. Prof. S. S. Bhatnagar, D.Sc., (Lahore).
 55. Prof. J. C. Ghosh, (Dacca).
 56. Dr. C. Srikantia, D.Sc., (Mysore).
 57. Rao Bahadur B. Vishwanath, F.I.C., (Pusa).
 58. Dr. B. M. Gupta, D.Sc., (Lucknow).
 59. Dr. S. S. Joshi, D.Sc., (Benares).
 60. Mr. K. P. Chatterji, M.Sc., F.C.S., (Allahabad).
 61. Dr. S. Dutt, D.Sc., (Allahabad).
 62. Dr. A. C. Chatterji, D.Sc., (Lucknow).
 63. Dr. Satyeswar Ghosh, D.Sc., (Allahabad).
 64. Dr. P. B. Ganguli, D.Sc., (Patna).

Botany

65. Prof. B. Sahni, D.Sc., Sc.D., F. R. S., (Lucknow).
 66. Dr. K. C. Mehta, Ph.D., (Agra).
 67. Prof. J. H. Mitter, Ph.D., MSc., (Allahabad).
 68. Prof. T. K. Parija, M.A., I.E.S., (Cuttack).

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| 69. | Dr. Bholanath Singh, D.Sc., | (Benares). |
| 70. | Dr. S. L. Ghosh, | (Lahore). |
| 71. | Dr. H. Chaudhari, | (Lahore). |
| 72. | Dr. Shri Ranjan, D.Sc. | (Allahabad). |
| 73. | Dr. Ram Kumar Saxena, D.Sc. | (Allahabad). |
| 74. | Dr. S. N. Das Gupta, | (Lucknow). |
| 75. | Prof. S. L. Ajrekar, B.A., I.E.S. | (Ahmedabad). |
| 76. | Dr. Y. Bharadwaja, | (Benares). |
| 77. | Mr. H. G. Champion, I.E.S., | (Dehra Dun). |
| 78. | Prof. P. Maheshwari, D.Sc., | (Agra). |
| 79. | Mr. P. K. Dey, I.A.S., | (Cawnpore). |

Geological Science

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| 80. | Dr. D. N. Wadia, D.Sc., | (Calcutta). |
| 81. | Prof. K. K. Mathur, | (Benares). |
| 82. | Mr. E. S. Pinfold, F.G.S. | (Rawalpindi). |

Zoology and Entomology

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| 83. | Prof. George Matthei, I.E.S. | (Lahore). |
| 84. | Prof. K. N. Bahl, D.Sc., | (Lucknow). |
| 85. | Prof. D. R. Bhattacharya, D.Sc., Ph.D., | (Allahabad). |
| 86. | Dr. H. R. Mehra, Ph.D., | (Allahabad). |
| 87. | P. B. Richards, Esq., A.R.C.S., | (Cawnpore). |
| 88. | Dr. C. C. John, | (Agra). |
| 89. | Dr. B. K. Das, D.Sc., | (Hyderabad, Deccan). |
| 90. | Dr. Ram Saran Das, D.Sc., | (Allahabad). |
| 91. | Dr. K. C. Pandya, Ph.D., | (Agra). |

Psychology and Medicine

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| 92. | Lt.-Col. R. N. Chopra, I.M.S., | (Calcutta). |
| 93. | Prof. W. Burridge, | (Lucknow). |

- 94. Dr. M. A. H. Siddiqui, M.A., M.B., D.L.O., (Lucknow).
- 95. Dr. A. Subba Rao, D.Sc., (Mysore).
- 96. J. M. Sen, Esq., F.R.G.S., (Calcutta).
- 97. Prof. N. N. Sen Gupta, Ph.D. (Lucknow).

Agriculture

- 98. Rao Bahadur G. N. Rangaswami Ayyangar, (Coimbatore).
- 99. R. L. Sethi, Esq., M.Sc. (Shahjehanpur).
- 100. Dr. K. C. Sen, D.Sc., (Muktesar).

The following members were elected Office-bearers and the Members of the Council for the year 1937 in the Annual Meeting held on Friday, 15, 1937.

President

- 1. Prof. B. Sahni, D. Sc., Sc.D., F.R.S., F.G.S.

Vice-presidents

- 2. Prof. D. R. Bhattacharya, D.Sc., Ph.D. F.Z.S.
- 3. Prof. P. S. MacMahon, B.Sc., M.Sc., F.I.C.

Hony. Treasurer

- 4. Dr. H. R. Mehra, M.Sc., Ph.D.

General Secretaries

- 5. Dr. S. M. Sane, B.Sc., Ph.D.
- 6. Dr. P. L. Srivastava, M.A., D. Phil, (Oxon).

Foreign Secretary

- 7. Dr. M. N. Saha. F.R.S.

Other Members of the Council

- 8. The Hon'ble Sir Shah Muhammad Sulaiman, Kt., M.A., LL.D.
- 9. Prof. N. R. Dhar, D.Sc., F.I.C., I.E.S.

10. Prof. George Matthai, D.Sc., I.E.S.
11. Prof. K. N. Bahl, D.Sc., D. Phil.
12. Dr. Shri Ranjan, D.Sc. (Toulouse),
13. Dr. J. C. Ghosh, D.Sc.
14. Dr. C. W. B. Normand, DSc.
15. Prof. A. C. Banerji, M.A., M.Sc., F.R.A.S., I.E.S.
16. Prof. P. K. Parija, I.E.S.

APPENDIX 2.**LIST OF OFFICE-BEARERS AND MEMBERS OF THE COUNCIL 1936.****President**

1. N. R. Dhar, D.Sc., F.I.C., I.E.S.

Vice-Presidents

2. K. N. Bahl, D.Sc., D. Phil.
3. A. C. Banerji, M.A., M.Sc., F.R.A.S., I.E.S.

Hony. Treasurer

4. H. R. Mehra, D. Phil.

General Secretaries

5. S. M. Sane, B.Sc., Ph.D.
5. P. L. Srivastava, M.A., D. Phil.

Foreign Secretary.

7. B. Sahni, D.Sc., Sc.D., F.R.S., F.G.S., F.A.S.B.

Other Members of the Council

8. K. C. Mehta, Ph.D.
9. M. N. Saha, F.R.S.
10. S. S. Joshi, D.Sc.
11. Ch. Wali Mohammad, M.A., Ph.D., I.E.S.
12. Shri Ranjan, D.Sc.
13. Rudolf Samuel, Ph.D.
14. J. A. Strang, M.A.
15. D. R. Bhattacharya, D.Sc., Ph.D., F.Z.S.
16. K. C. Pandya, Ph.D.

APPENDIX 3.

ORDINARY MEMBERS

*—Denotes a fellow.

†—Denotes a Fellow of the National Institute of Sciences of India.

| Date of Election | Alphabetical List of ordinary Members |
|---------------------|---|
| 31-10-35 | Agarwal, Rai Amar Nath, Bari Kothi, Daraganj, Allahabad. |
| 20-4-1926 | * Ahmad, Ziauddin, (Dr.) Vice-Chancellor, Muslim University, Aligarh. |
| 20-4-35 † * | Ajrekar, Shripad Lakshman, B.A., I.E.S., Professor of Botany, Gujarat College, Ahmedabad. |
| 17-4-31 | * Asundi, R. K., Ph.D., Reader, Physics Department, Muslim University, Aligarh. |
| 10-5-35 † * | Ayyangar, G. N. Rangaswami, Rao Bahadur, B.A., I.A.S., Millets specialist to the Government of Madras, Agricultural Research Institute, P.O. Lawley Road, Coimbatore. |
| 1-1-30 † * | Bahl, K. N., D.Phil, D.Sc., Professor of Zoology, Lucknow University, Lucknow. |
| 1-1-30 † * | Banerji, A.C., M.A., M.Sc., F.R.A.S., I.E.S., Professor of Mathematics, Allahabad University, Allahabad. |
| 29-2-32 | Banerji, G.N. The Scientific Instrument Company, Ltd., Hornby Road, Bombay. |
| 22-12-32 | † * Banerji, S. K. D.Sc., Meteorologist, Ganeshkhind Road, Poona 5. |
| 17-4-31 | Basu, Saradindu, M.Sc., Meteorologist, Ganeshkhind Road, Poona 5. |
| 20-4-1936 | * Basu, N.M., D.Sc., Bakshi Bazar, Dacca. |
| 31-10-35 | * Bharadwaja, Yajnavalkya, D.Sc., Professor of Botany, Hindu University, Benares. |
| 19-3-31 | * Bhargava, Saligram, M.Sc., Reader, Physics Department, Allahabad University, Allahabad. |
| 17-4-31 | Bhargava, Vashishta, M.Sc., I.C.S., Sessions and Subordinate Judge, Agra. |

- 17-4-31 Bhatia, K.B., I.C.S. Magistrate and Collector, Shahjahanpur.
- 17-12-35 Bhatia, M.L., M.Sc., Lecturer in Zoology, Lucknow University Lucknow.
- 21-4-33 † * Bhatnagar, S.S., D.Sc., O.B.E., Professor of Chemistry, Government College, Lahore.
- 15-9-1936 Bhatnagar, Birendra Kumar, B.Sc., 207 McDonnel University Hindu Hostel, Allahabad.
- 20-12-34 Bhattacharya, A. K., D.Sc., Chemistry Department, Allahabad University, Allahabad.
- 1-1-31 † * Bhattacharya, D.R., M.Sc., Ph.D., Docteur ès Sciences, Professor of Zoology, Allahabad University, Allahabad.
- 17-4-31 Bhattacharya, D.P., M.Sc., Bareilly College, Bareilly..
- 31-10-35 Biswas, B.N., Professor of Physics, Raja Ram College, Kolhapur (S.M.C.)
- 31-10-36 † * Bose, D.M., M.A., B.Sc., Ph.D., Palit Professor of Physics, University College of Science and Technology, 92 Upper Circular Road, Calcutta.
- 20-4-1936 * Bose, N.K., Ph. D., Mathematical Officer Irrigation Research Institute, Lahore.
- 20-4-1936 † * Burridge, W., D.M., M.A. (Oxon). Professor of Physiology, Lucknow University, Lucknow.
- 1-2-1936 Caleb, J., B.Sc., M.Sc., L.T., Biology Department, Ewing Christian College, Allahabad.
- 3-4-33 Chand, Tara, M.A., D. Phil., Principal, K. P. University College, Allahabad.
- 9-11-35 Chak, Chandramohan Nath, M.Sc., Professor of Education Secondary Training College, Bombay.
- 31-10-35 Chakravarty, D. N., D.Sc., Professor, King Edward College, Amraoti, Berar.
- 10-5-35 † * Champion, H.G., M.A., Sylviculturist, Imperial Forest Research Institute, Dehradun.
- 29-2-32 Charan, Shyama, M.A., M.Sc., Agra College, Agra.
- 1-1-30 † * Chatterji, G., M.Sc., Meteorologist, Upper Air Observatory, Agra.

- 17-4-31 * Chatterji, K.P., M.Sc., A.I.C., F.C.S., Reader, Chemistry Department, Allahabad University, Allahabad.
- 17-4-31 * Chatterji, A.C., D.Sc., Dr. Ing., Chemistry Department, Lucknow University, Lucknow.
- 9-2-34 Chaturvedi, Champa Ram, Pandit, Professor of Mathematics, St. John's College, Agra.
- 31-10-34 † * Chaudhury, H., M.Sc., Ph.D., D.I.C., Head of the Department of University Teaching in Botany, Punjab University, Lahore.
- 17-1-31 Chaudhury, H.P., M.Sc., Lucknow University, Lucknow.
- 17-12-35 Chudhury, K. Ahmad, M.Sc., Wood Technologist, Imperial Forest Research Institute, Dehra Dun.
- 19-3-31 Chaudhury, Rabindra Nath, M.Sc., M.A., Mathematics Department, Allahabad University, Allahabad.
- 10-5-35 † * Chopra, R. N., Lt.-Col., C.I.E., M.B., I.M.S., Director, School of Tropical Medicine, Central Avenue, Calcutta.
- 31-10-35 Dabaghao, V.M., Physics Department, College of Science, Nagpur.
- 19-8-31 * Das, Ramsaran, D.Sc., Zoology Department, Allahabad University Allahabad.
- 17-4-31 Das, C. Maya, M.A., B.Sc., I.A.S., Dy. Director of Agriculture, Sarda Circle, U. P. Lucknow.
- 28-10-32 * Das, A.K., D.Sc., Upper Air Observatory, Agra.
- 22-12-32 * Das, B.K., D.Sc., Professor of Zoology, Osmania University, Hyderabad, Deccan.
- 29-7-1936 Dass, A.T. Dharam, M.Sc., 13, Strachey Road, Allahabad.
- 17-12-35 * Das Gupta, S.N., M.Sc., D.I.C., Ph.D., Reader in Botany, Lucknow University, Lucknow.
- 15-9-31 Dasannacharya, B., Ph.D., Professor of Physics, Benares Hindu University, Benares.
- 20-4-1936 † * Datta, S., D.Sc., D.I.C., Professor of Physics, Presidency College, Calcutta
- 17-4-31 * Deodhar, D.B., Ph.D., Reader, Physics Department, Lucknow University, Lucknow,

- 31-10-35 * Desai, M.S., M.Sc., Professor of Physics, M. T. B. College, Surat.
- 17-4-31 Dey, P.K., M.Sc., I.A.S., Plant Pathologist to Government, United Provinces, Nawabganj, Cawnpore.
- 29-2-32 Deb, Suresh Chandra, D.Sc., Research Physicist, Bose Institute, Calcutta.
- 1-1-30 † * Dhar, N. R., D.Sc., Docteur ès Sciences, F.I.C., I.E.S., Professor of Chemistry, Allahabad University, Allahabad.
- 31-10-35 Dube, Ganesh Prasad, M.Sc., Lecturer in Physics, Balwant Rajput College, Agra.
- 19-3-31 Dutt, S.K., M.Sc., Zoology Department, Allahabad University, Allahabad.
- 17-4-31 † * Dutt, S.B., D.Sc., Reader, Chemistry Department, Allahabad University, Allahabad.
- 28-10-32 Dutt, A.K., D.Sc., Research Physicist, Bose Institute, Calcutta.
- 20-4-1936 * Ganguli, P.B., D.Sc., Professor of Chemistry, Science College, Bankipore P.O., Patna.
- 22-2-33 Ghatak, Narendranath, M.Sc., D.Sc., Chemical Assistant to Indian Stores Department, Government Test House, Alipore, Calcutta.
- 19-4-31 Ghosh, B.N., M.Sc., St. Andrew's College, Gorakhpur.
- 8-11-33 † * Ghosh, J.C., D.Sc., Professor of Chemistry, The University, Dacca.
- 19-3-31 * Ghosh, R.N., D.Sc., Physics Department, Allahabad University, Allahabad.
- 19-3-31 * Ghosh, Satyeshwar, DSc., Chemistry Department, Allahabad University, Allahabad.
- 20-4-1936 † * Ghosh, S.L., Professor of Botany, Government College, Lahore.
- 20-4-1936 * Ghosh, J., M.A., Ph. D., Professor Mathematics, Presidency College, Calcutta.
- 15-9-31 Gogate, D.V., M.Sc., Baroda College, Baroda.
- 15-9-31 Gordon, C.B., B.A., Christ Church College, Cawnpore.

- 31-10-35 * Gulatee, B.L., M.A., Mathematical Advisor, Survey of India, Dehra Dun.
- 17-4-31 * Gupta, B.M., Ph.D., Deputy Public Analyst to Government, United Provinces, Lucknow.
- 17-4-31 Higginbottom, Sam, D. Phil., Principal, Allahabad Agricultural Institute, Naini, E. I. R., Allahabad.
- 17-4-31 * Hunter, Robert, F., D.Sc., Ph.D., Professor of Chemistry, Muslim University, Aligarh.
- 21-12-1936 Husain, Zahur., B.A. (Hons). C/o Prof. A.K. Nyazee, M.A., Superintendent, The 'Quadrangle' Hostel, Government College, Lahore.
- 3-4-34 Joshi, A.D., P.E.S., Lecturer, Training College, Lucknow.
- 20-4-1936 * John, C.C., Professor of Zoology, Agra University, Agra.
- 21-12-31 * Joshi, S.S., D.Sc., Professor of Chemistry, Benares Hindu University, Benares.
- 15-9-31 † * Kichlu, P.K., D.Sc., Department of Physics, Government College, Lahore.
- 21-4-33 Kishen, Jai, M.Sc., Professor of Physics, S.D., College, Lahore.
- 9-2-34 † * Kothari, D.S., M.Sc., Ph.D., Professor of Physics, The University, Delhi.
- 3-4-34 † * Krishna, Shri, Ph.D., D.Sc., F.I.C., Forest Biochemist, Imperial Forest Research Institute, Dehra Dun.
- 5-10-33 Kureishy, A.M., M.A., Reader in Mathematics, Muslim University, Aligarh.
- 31-10-35 Lal, Rajendra Bihari, M.Sc., Assistant Traffic Superintendent, E.I.R., C/o Babu Basant Behari Lall, B.A., Partabgarh City (Oudh).
- 20-4-35 † * Mahalanobis, P.C., M.A., I.E.S., Professor of Physics, Statistical Laboratory, Presidency College, Calcutta.
- 1-1-30 † * MacMahon, P.S., B.Sc., (Hons.), M.Sc., Professor of Chemistry, Lucknow University, Lucknow.
- 31-10-35 † * Meheshwari, Panchanan, D.Sc., Associate Professor of Botany, Agra College, Agra.

- 31-10-35 Majumdar, R.C., M.Sc., Ph.D., The Bose Institute, 93 Upper Circular Road, Calcutta.
- 26-9-34 Malaviya, Braj Kishore, M.Sc., Public Health Department, Allahabad Municipal Board, Allahabad.
- 31-10-35 * Mathur, K.N., D.Sc., Lecturer in Physics, Lucknow University, Lucknow.
- 31-10-35 Mathur, Lakshmi Sahay, M.Sc., Physics Department, Allahabad University, Allahabad.
- 17-12-35 † * Matthai, George, M.A., Sc.D. F.R.S.E. I.E.S., Professor of Zoology, Punjab University, Lahore.
- 1-1-30 † * Mehta, K.C., Ph.D., M.Sc., Agra College, Agra,
- 1-1-30 * Mitter, J.H., M.Sc., Ph.D., Professor of Botany, Allahabad University, Allahabad.
- 15-9-31 Mathur, L.P., M.Sc., St. John's College, Agra.
- 8-11-33 Mathur, Ram Behari, M.Sc., Professor of Mathematics, St. Stephen's College, Delhi.
- 19-3-31 Mazumdar, Kanakendu, D.Sc. Physics Department, Allahabad University, Allahabad.
- 19-3-31 † * Mehra, H.R., Ph.D., Reader, Zoology Department, Allahabad University, Allahabad.
- 16-8-35 Mehrotra, Braj Mohan, M.A., Ph.D., Mathematics Department, Benares Hindu University, Benares.
- 21-12-31 Mehta, N.C., I.C.S., Secretary, Imperial Council of Agricultural Research, New Delhi.
- 21-4-33 Mela Ram, M.Sc. Asst. Professor of Physics, Foreman Christian College, Lahore.
- 31-10-35 Mohan, Ananda, B.Sc., Assistant Traffic Superintendent, E.I.R., Chief Commercial Manager's Office, 105 Clive Street, Calcutta.
- 31-10-35 Mohan, Piare, M.Sc. Department of Mathematics, Allahabad University, Allahabad.
- 20-4-35 † * Mowdawalla, F.N., M.A., M.I.E.E., Mem. A.I.E.E., M.I.E., Chief Electrical Engineer, Bangalore.

- 21-4-33 Mukerjee, Ashutosh, M.A., Principal, Science College, P.O. Bankipore (Patna).
- 31-10-35 Mukerji, S., D.Sc., Kala Azar Enquiry, School of Tropical Medicine, Calcutta.
- 1-1-30 * Narayan, Luxmi, D.Sc., Reader, Mathematics Department Lucknow University, Lucknow.
- 22-2-33 * Narliker, V.V., M.A., Professor of Mathematics, Benares Hindu University, Benares.
- 17-4-31 * Nehru, S.S., M.A., Ph.D., I.C.S., Magistrate and Collector, Mainpuri U.P.
- 20-4-35 † * Normand, C. W. B., M.A., D.Sc. Director General of Observatories, Poona.
- 31-10-35 Oak, V. G. M.Sc., I.C.S., Joint Magistrate, Allahabad.
- 17-4-31 * Pandya, K.C., Ph. D., St. John's College, Agra.
- 16-8-35 Pande, Kedar Dat, M.Sc., Government Intermediate College Moradabad.
- 20-4-1936 † * Paranjpye, R.P., D.Sc. Vice-Chancellor Lucknow University Lucknow.
- 3-4-33 † * Parija, P.K., M.A., I.E.S., Ravenshaw College, Cuttack.
- 29-7-1936 Pendse, G.P., M.Sc., Chemistry Department, Victoria College, Gwalior. C.I.
- 10-5-35 † * Pinfold, Ernest Sheppard, M.A., F.G.S., Geologist, Attock Oil Co. Ltd., Rawalpindi.
- 18-9-35 * Pramanik, S.K., M.Sc., Ph.D., D.I.C., Meteorologist, Meteorological Office, Poona 5.
- 5-10-33 * Prasad, Gorakh, D.Sc., Reader in Mathematics, Allahabad University, Allahabad.
- 16-8-35 Prasad, Jalpa, M.Sc., Chemistry Department, K. P. Inter. College, Allahabad.
- 21-4-33 * Prasad, Kamta, M.A., M.Sc., Professor of Physics, Science College, P.O. Bankipore (Patna)...
- 15-9-31 † * Prasad, Mata, D.Sc., Royal Institute of Science, Bombay.

- 8-4-33 ♦ Prasad, Badri Nath, Ph.D., Docteur ès Science, Mathematics Department, Allahabad University, Allahabad.
- 17-4-31 Puri, B. D., M.A. Thomason Civil Engineering College, Roorkee.
- 22-12-32 † * Qureshi, M., M.Sc., Ph.D., Professor of Chemistry, Osmania University College, Hyderabad, Deccan.
- 20-12-34 Rai, Ram Niwas, M.Sc., Physics Department, Allahabad University, Allahabad.
- 3-4-33 * Ram, Raja, M.A., B.E. Malaria Engineer, Kasauli.
- 19-3-31 * Ranjan, Shri, M.Sc., Docteur es Sciences, Reader, Botany Department, Allahabad University, Allahabad.
- 15-9-31 * Rao, A. Subba, D.Sc., Medical College, Mysore.
- 22-2-33 Rao, G. Gopala, B.A., M.Sc., D.Sc., Chemistry Department, Andhra University, Waltair.
- 21-12-31 Rao, D. H. Ramchandra, B.E., A.M.I.E., Engineer, Allahabad University, Allahabad.
- 20-4-35 * Rao, I. Rama Krishna, M.A., Ph.D., D.Sc., Department of Physics, Andhra University, Waltair.
- 14-3-34 Rao, K. Rangadhama, B.Sc., Physics Department, Andhra University, Waltair.
- 20-4-1936 * Rao, S. Ramchandra, M.A., Ph. D. (Lond), F. Inst. P. Professor of Physics, Annamalai University, Annamalainagar P.O., (South India).
- 1-2-1936 Ray, J.P., M.Sc., Professor, D.A.V. College, Dehra Dun.
- 22-2-33 * Ray, Bidhubhusan, D.Sc., 92 Upper Circular Road, Calcutta.
- 21-12-31 Ray, Satendra Nath, M.Sc. Physics Department, Lucknow University, Lucknow.
- 1-1-30 * Richards, P.B., A.R.C.S., F.E.S., Entomologist to the Government, United Provinces, Cawnpore.
- 1-1-30 † * Saha, M.N., D.Sc., F.R.S., F.A.S.B., F. Inst. P., P.R.S. Professor of Physics, Allahabad University, Allahabad.
- 29-2-32 Saha, Jogendra Mohan, M.Sc., Manager, Sitalpur Sugar Works, P.O. Dighwara. Dist. Saran
- 1-1-30 † * Sahni, B., D.Sc., Sc.D., F.R.S., F.G.S., F.A.S.B., Professor of Botany, Lucknow University, Lucknow.

- 17-4-31 * Samuel, Rudolf, Ph.D., Professor of Physics, Muslim University, Aligarh.
- 17-4-31 * Sane, S. M., B.Sc., Ph.D., Reader, Chemistry Department Lucknow University, Badshah Bagh, Lucknow.
- 1-2-1936 * Saxena, Ram Kumar, D.Sc., Lecturer in Botany, Allahabad University, Allahabad.
- 31-10-35 † * Sen, Jitendra Mohan, M. Ed., B.Sc. Teacher's Dip., F.R.G.S., D.Ed. Assistant Director of Education, Bengal, Calcutta.
- 3-4-38 * Sen, K. C., D.Sc., Officer-in-charge, Animal Nutrition Section, Imperial Veterinary Research Institute, Izatnagar, U. P.
- 20-4-35 † * Sen, Nikhil Ranjan, M.Sc., Professor of Mathematics, 92 Upper Circular Road, Calcutta.
- 17-12-35 † * Sen Gupta, N. N., Ph.D., Professor of Psychology, Lucknow University, Lucknow.
- 20-12-34 Sen Gupta, P. K. D.Sc. Professor of Physics, Rajaram College, Kolhapur. Bombay Presidency.
- 21-4-33 * Seth, J. B., M.A., Government College, Lahore.
- 17-4-31 Seth, S. D. M.Sc., Christ Church College, Cawnpore.
- 1-1-30 * Sethi, R. L., M.Sc., M.R.A.S., Economic Botanist to Government, United Provinces, Cawnpore.
- 19-3-31 * Sethi, Nihal Karan, D.Sc., Agra College, Agra.
- 31-10-35 Shabde, N. G., D.Sc., Professor of Mathematics, College of Science, Nagpur.
- 3-4-34 Shah, S. M., M.A., Mathematics Department, Muslim University, Aligarh, U. P.
- 31-10-35 Sharma, P.N.; M.Sc., Physics Department, Lucknow University, Lucknow.
- 15-9-31 Sharma, Ram Kishore, M.Sc., Physics Department, Ewing Christian College, Allahabad.
- 18-9-35 Shukla, Janardan Prasad, M.Sc., Manufacturing Chemist, Oudh Sugar Mills, Hargaon, (R.K.Ry.) U. P.
- 3-4-33 * Siddiqi, M.R., Ph.D., Professor of Mathematics, Osmania University, Hyderabad, Deccan,

- 3-4-33 * Sidiqui, Mohammad Abdul Hamid, M.A., M.S., F.R.C.S., D.L.O., Professor of Anatomy, King George's Medical College, Lucknow.
- 17-4-31 Singh, Avadhesh Narain, D.Sc., Department of Mathematics, Lucknow University Lucknow.
- 17-12-35 * Singh, Bhola Nath, D.Sc., Kapurthala Professor of Agricultural Botany and Plant Physiology, Head of the Institute of Agricultural Research, Hindu University, Benares.
- 17-4-31 Soonawala, M.F., M.Sc., Maharaja's College, Jaipur (Rajputana).
- 18-9-35 Srivastava, Bishwambhar Nath, M.Sc., Lecturer, Physics Department, Allahabad University, Allahabad.
- 19-3-31 † * Srivastava, P.L., M.A., D. Phil., Reader, Mathematics Department, Allahabad University, Allahabad.
- 10-8-33 * Srivastava, R.C., B.Sc., (Tech), Sugar Technologist, Imperial Council of Agricultural Research, India, Cawnpore.
- 25-3-1936 Srivastava, Har Dayal, M.Sc., Offg. Helminthologist, Imperial Institute of Veterinary Research, Muktesar.
- 15-9-31 * Shrikantia, C., B.A., D.Sc., Medical College, Mysore.
- 19-12-32 * Strang, J.A., M.A., B.Sc., Professor of Mathematics, Lucknow University, Badshah Bagh, Lucknow.
- 24-1-33 Subramanian, S., M.A., Mathematics Department, Annamalai University, Annamalainagar P. O., South India.
- 17-4-31 * Sulaiman, S.M., Hon'ble Sir, Chief Justice, High Court, Allahabad.
- 20-4-1936 * Sur, N.K., D.Sc., Meteorologist, Upper Air Observatory, Agra.
- 19-3-31 Taimini, Iqbal Kishen, Ph.D., Chemistry Department, Allahabad University, Allahabad.
- 17-12-35 Tandon, Amar Nath, M.Sc., Physics Department, Allahabad University, Allahabad.
- 9-11-35 Tandon, Prem Narain, M.Sc., I.C.S., Joint Magistrate, Gaya, (B. & O.)

| | |
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| 3-4-33 | Thompson, C.D., M.A., Professor of Economics, Allahabad University. |
| 19-3-31 | Toshniwal, G.R., M.Sc., Physics Department, Allahabad University, Allahabad. |
| 15-9-1936 | Trivedi, Hrishikesha, M.Sc., D.Sc., Physical Assistant, Government Test House, Judge's Court Road, Alipur. (Calcutta) |
| 3-4-34 | Varma, Rama Shanker, M.Sc., Christ Church College, Cawnpore. |
| 20-12-34 | Varma, S.C., M.Sc., Zoology Department, Allahabad University, Allahabad. |
| 9-2-34 | Vaugh, Mason, B.Sc., (Ing.), Agricultural Engineer, Allahabad Agricultural Institute, Naini, (E.I.Ry.) (Allahabad). |
| 19-3-31 † * | Vijayaraghavan, T., D.Phil., Reader, Mathematics Department, Dacca University, Ramna, Dacca. |
| 20-4-35 † * | Vishwanath, B., Rai Bahadur, F.I.C., Imperial Agricultural Chemist, Imperial Agricultural Research Institute, New Delhi |
| 20-4-35 † * | Wadia, D.N., M.A., B.Sc., F.G.S., F.R.G.S., Geological Survey of India, 27 Chowringhee, Calcutta. |
| 1-1-30 † * | Wali, Mohammad, Ch., M.A., Ph.D., I.E.S., Professor of Physics, Lucknow University, Lucknow, |
| 15-9-31 | Wall, W.G.P., M.Sc., I.E.S., Associate I.E.E., M.R.S.T., Principal, Training College, Allahabad. |

N.B.—The Secretaries will be highly obliged if the members will kindly bring to their notice errors, if there be any, in their titles, degrees, and addresses.

APPENDIX 4

List of Exchange JournalsINDIA

| Publisher | <u>INDIA</u> | Journal |
|---|--------------|---|
| BANGALORE | | |
| The Indian Academy of Science | | Proceedings of the Indian Academy of Sciences, Section A. |
| DO. | | DO. Section B. |
| The Indian Institute of Science | | Journal of the Indian Institute of Science, Section A |
| DO. | | DO. Section B. |
| The Indian Institute of Science | | Current Science. |
| Department of Electrical Technology, Indian Institute of Science | | Electrotechnics. |
| CALCUTTA | | |
| Asiatic Society of Bengal | | Journal of the Asiatic Society of Bengal (Letters) |
| DO. | | Journal of the Asiatic Society of Bengal (Science) |
| DO. | | Year Book |
| DO. | | Journal and Proceedings of the Asiatic Society of Bengal. |
| National Institute of Sciences of India | | Transactions of the National Institute |
| DO. | | Indian Science Abstracts. |
| DO. | | Proceedings of the National Institute |
| Indian Association for Cultivation of Science | | Indian Journal of Physics |
| DO. | | Proceedings of the Indian Association for the Cultivation of Science. |

Bose Research Institute

Transactions of the Bose
Research Institute

Indian Science News Association

Science and culture
The Journal of the Indian
Chemical Society

Indian Chemical Society

Indian Mathematical Journal

Oxford University Press.

COONOR

Nutrition Research Laboratories,
Indian Research Fund Association

Publications of the Laboratories

NEW DELHI

Industrial Research Bureau

Bulletins of the Indian Industrial
Research

Imperial Council of Agricultural
Research (Library Section)

Indian Journal of Agricultural
Science

DO.

Indian Journal of Veterinary
Science and Animal Husbandry
Scientific Monographs of the
Imperial Council of Agricultural
Research

DO.

MADRAS

Department of Fisheries

Journals, Administration Report,
Bulletin of the Madras Govern-
ment Museum. Natural History
Section

Connemara Public Library, Egmore

Nagpur University Journal

NAGPUR

Nagpur University

PATNA

Philosophical Society, Patna Science
College

Bulletin of the Patna Science
College Philosophical Society

POONA

Indian Meteorological Department

Scientific notes

DO.

Memoirs of the Indian Meteoro-
logical Department

FOREIGN

AUSTRALIA

ADELAIDE

The Royal Society of South Australia

Transactions of the Royal Society of South Australia

EAST MELBOURNE

Council for Scientific and Industrial Research

Journal of the Council for Scientific and Industrial Research

Radio Research Board, Council for Scientific and Industrial Research

Bulletin of the Radio Research Board

Council for Scientific and Industrial Research

Pamphlet of the Council for Scientific and Industrial Research

DO.

Annual Report

MELBOURNE

Royal Society of Victoria

Proceedings of the Royal Society of Victoria.

SYDNEY

Royal Society of New South Wales

Journal and Proceedings of the Royal Society of New South Wales

AUSTRIA

VIENNA

Akademie der Wissenschaften

Anzeiger (Mathematisch-Naturwissenschaftliche Klasse)

DO.

Anzeiger (Philosophisch-historische Klasse)

DO.

Almanach

BELGIUM

BRUSSELS

Academic Royale de Belgique

Bulletin de la Classe Des Sciences

BRAZIL

RIO DE JENERIO

Institute Oswaldo Cruz

Memorias do Instituto Oswaldo Cruz

CANADA

OTTAWA

The Royal Society of Canada

Transactions of the Royal Society
of Canada
Annual Report

TORONTO

The Royal Astronomical Society of
CanadaJournal of the Royal Astronomical
Society of Canada

VICTORIA

The Dominion Astrophysical
ObservatoryPublications of the dominion
Astrophysical Observatory.

NANKING

The Metropolitan Museum of
Natural History, Academia Sinica

Sinensis

DO

Academia Sinica Memoir

SHANGHI

National Research Institute of
Physics Academia SinicaScientific Papers of the national
Research Institute of Physics,
Academia SinicaDENMARK

COPENHAGEN

Kongelige Dansk
Videnskabernes Selskab

Mathematisk-Fysiske Meddelelser

DO

Biologisko Meddelelser

DO

Memoires

KOBENHARN, VALBY

The Bibliothcaire Carlsberg
LaboratoriumComptes-Rendus Des Travaux
Den Laboratoire Carlsberg.EGYPT

CAIRO

The Egyptian Medical Association

Journal of the Egyptian Medical
Association.

ENGLAND

ABERDEEN

Imperial Bureau of Animal Nutrition
The Reid Library, Rowett
Institute.

Technical Communications

ABERYSTWYTH

Imperial Bureau of Plant Genetics,
Herbage Plants, Agricultural
Buildings.

Bulletins

ST. ALBANS HERTS,

Imperial Bureau of Agricultural
Parasitology

Helminthological Abstracts

DO

CAMBRIDGE

Imperial Bureau of Plant Genetics,
School of Agriculture.

Bibliography of Helminthology

The Philosophical Society

Plant breeding Abstracts.

EDINBURGH

The Royal Society of Edinburgh

Proceedings of the Cambridge
Philosophical Society

HARPENDEN

Imperial Bureau of Soil Science,
Rothamsted Experimental Station.

Proceeding of the Royal Society
of Edinburgh

DO

Technical Communications

DO

Reprints

EAST MALLING (KENT)

Imperial Bureau of Fruit Production.

Reports.

Eeast Malling Research Station

Horticultural Abstracts

LONDON

The Electrician, Bonverie House

Electrician

MIDDLESEX

The National Physical Laboratory,
Teddington

Reports

FRANCE

PARIS

Institute Henri Poincare

De La Station Biologique,

Annuals De L' Institute Henri
PoincareTravaux De la
Station BiologiqueGERMANY

BERLIN

Preussischen Akademie der
Wissenschaften

Deutsche Chemische Gesellschaft

Sitzungsberichte Der Preussischen
AkademieBerichte Der Deutschen Chemischen
Gesellschaft

GOTTIGEN

Geasellschaften Wissencehalten
Zu GottingenNachrichten Von der Gasellschaftde
Wissenschaften Zu Gottingen

do

Mathematich Physikalische Klasse

do

Fachgruppe I. Mathematik

do

" II. Physik, Astronomie,
Geophysik, Technik.

do

" III. Chemie, Einschl,
Physikalische Chemie.

do

" IV. Geologie und Miner-
ologie

do

" V. Geographie.

do

" VI. Biologie.

do

Geschäftliche Mitteilungen

HEIDELBERG

The Bibliothekar Heidelberger
Akademie der WissenchaftenSitzungsberichte, Mathematische
Naturwissenschaftliche Klasse

LEIPZIG

Sachoische Akademie der
WissenchaftenBerichte Der Mathematische Physis-
chen Klasse

do

Abhandlungen Der Mathematische-
Physischen Klasse

do

Prävariskisch Glieder Der Sächsisch-
Fichtelgebirgischen Kristallinen
Schiefer.

MUNCHEN

Bayerische Akademie Der
Wissenschaften Zu Munchen

Sitzungsberichte de Mathematisch
Naturwissenschaftlichen

GRONINGEN

Kapteyn Astronomical Laboratory,

Publications of the Kapteyn
Astronomical Laboratory

LEIDEN

Library of the Kamerlingh Onnes
Laboratory, Neuwsteeg

Communications from the Physica
Laboratory

DO

Communications from Kamerlingh
Onnes Laboratory

HUNGARY

BUDA PEST

The Ungarische Akademie de
Wissenschaft

Mathematische Und Naturwissen-
schaftliche Berichte Ana Ungaru

ITALY

PALERMO

Rendiconti Del Circolo Methematico
Di Palermo 30, Via
Ruggero Settimo

Rendiconti

JAPAN

CHOSEN

Medical Faculty, Keijo Imperial
University

The Keijo Journal of Medicine

HIROSHIMA

Hiroshima University

Journal of Science of the
Hiroshima University (Zoology)

OSAKA

Library of the faculty of Science,
Osaka Imperial University

Collected papers from the faculty
of Science

SAPPORO

The faculty of Science, Hokkaido
Imperial University

Journal of the faculty of Science.
Series I, Mathematics

SENDAI

Imperial University of Tohoku

TOKYO

The Imperial Academy

The Institute of Physical and
Chemical Research,The National Research council of
Japan

DO

DO

DO

DO

DO

The Physico-Mathematical Society
of JapanScience Report of the Tohoku
Imperial UniversityProceedings of the Imperial
Academy

Scientific Papers

Japanese Journal of Mathematics

Japanese Journal of Botany

Japanese Journal of Physics

Japanese Journal of Astronomy
and Geophysics

Report

Report of Radio Research

Proceedings of the Physico-
Mathematical Society of JapanPOLAND

CRACOVIE

Academic Polonaise Des Sciences et
Des Letters

DO

Comptes Rendus Mensuels Des
Séances De La Classe Des
Sciences Mathématiques et
NaturellesComptes Rendus Mensuels Des
Séances De La Classe De
Medecine

CRACOVIE

Imprimerie De L'Université

DO

Bulletin International De
L'Académie Polonaise Des
Sciences et Des Letters Classe
Des Sciences Mathématiques et
Naturelles Série A: Sciences
Mathématiques
Bulletin International De

L'Academie Polonaise Des Sciences
et Des Sciences Mathématiques et
Naturelles Serie B: Sciences
Naturelles (I)

| | DO | DO | (II) |
|-----|----|--|------|
| DO | | Bulletin International De | |
| DO | | L'Academie Polonaise Des Sciences et Des Letters Classe de Medicine | |
| DO | | Memoirs de L'Academie Polonaise Des Sciences et Des Letters Classe De Medicine | |
| DO | | Comptes Rendus Mensuels de Sciences De la Classe de Medicine | |
| ci, | | Starzenia | |
| DO | | Travaux Geologiques | |
| DO | | Sprawozdanie Z posiedzen Tow- arzystwa Nankowego Warszaw- skiego I (Historji Literatury) | |
| DO | | Sprawozdania Z posiedzen Towarzystwa Naukowego Wasszawskiego II (Filozoficznych) | |
| DO | | Sprawozdania Z posiedzen Tow- arzystwa Nankowego Waaszaw- skiego III (Matematyczno- fizycznych) | |
| DO | | Sprowozdania Z posiedzen Tow- arzystwa Naukowego Warsz- awskiego IV (Biolgicznych) | |

WARSAW

Society Polonaise de Physique

Acta Physica Polonica

NEW ZEALAND

WELLINGTON

New Zealand Institute, Victoria
University College

34 Transactions and Proceedings of
the Royal Society of New
Zealand.

SOUTH AFRICA

RONDEBOSCH

Royal Society of South Africa,
University of Cape Town

Transactions of the Royal
Society of South Africa

SWEDEN

LUND

The University

Kungi Fysiografiskar Sällskapets
Forhandlingar

STOCKHOLM

Kungliga Svenska
Vetenskapsakademie

Geographical and Biological
Studies of Anopheles
Maculipennis in Sweden

UPPSALA

The Universitat

Uppsala Universitets
Arsskrift

SWITZERLAND

GENEVA

Societe d'Historie Naturelle et
de Physique

Compte Rendu des Seances
De La Societe De Physique et
d'Histoire Naturalle

UNITED STATES OF AMERICA

ALLEGHENY CITY

Allegheny Observatory of the
University of Pittsburgh

Publications of the Allegheny
Observatory

CALIFORNIA

The Mount Wilson Observatory
Pasadena

Contributions from the Mount
Wilson Observatory

DO

Conununications from the Mount
Wilson Observatory

DO

Report of the Director of the
Mount Wilson Observatory

Exchange Department, University
Library, Berkeley

Publications in Zoology, Uni
versity of California

CAMBRIDGE MASS

Massachusetts Institute of
Technology

CHICAGO

The University of Chicago

BERKELEY

Lick Observatory, University of
California

BOSTON

American Academy of Arts and
Sciences

DO

LAWRENCE, KANSAS

The University of Kansas

MICHIGAN

Observatory Library, University of
Michigan

NEW YORK

American Telephone and Telegraph
Company

Roosevelt Wild Life Forest
Experiment Station

New York Academy of Sciences

NEW HAVEN (YALE)

Astronomical Observatory of Yale
University

* Secretary American Journal of
Science

American Institute of Physics

DO

Journal of Physics and Mathematics

Astrophysical Journal

Lick Observatory Bulletin

Proceedings of the American Aca-
demy of Arts and Sciences

Memoirs of the American Academy
of Arts and Sciences

Science Bulletin

Publications of the Observatory
of the University of Michigan

Bell System Technical Journal

Roosevelt Wild Life Annals

Annals of the New York Academy
of Sciences

Transactions of the Astronomical
Observatory, Yale University

American Journal of Science

Review of Scientific Instruments

Journal of Chemical Physics

Bill Telephone Laboratories

The American Museum of Natural History

PHILADELPHIA

The Franklin Institute of the State of Pennsylvania

American Philosophical Society

Academy of Natural Sciences

do

do

WOODS HALE, MASS

Marine Biological Laboratory Library

WASHINGTON

The National Academy of Sciences

Smithsonian Institute

Department of Commerce, Bureau of Standards

The commissioner of fisheries

Bill Telephone System Technical

Publications

American Museum Novelties

Journal of the Franklin Institute

Proceedings of the American Philosophical Society

Proceedings of the Academy of Natural Sciences of Philadelphia

Miscellanea

Library Annual Report

The Biological Bulletin

Proceedings of the National Academy of Sciences

Publications

Publications of the Bureau of Standards

Publications

UNITED STATES OF SOVIET RUSSIA

KHARKOV

Chikovsakya 16.

Physikalische Zeitschrift Der Sorojetunion

LENINGRAD

The Skademiie der Wissenschaft

Bulletin De L'Academie Des Sciences Mathematiques et Naturelles

MOSCOW

De L'Academie De Sciences de L'urss

Comptes Rendus (Doklady)

De L'Academie Der Sciences

Comptes Rendas (Doklady)

De L'urss

UKRAINE

Academie des Sciences D'Ukraine

Kyiv

Journal De Cycle Physique et
De Chemie

DO

Journal Der Cycle Mathematique

DO

Bulletin de La Classe des
Sciences Physiques et Mathe-
matiques

DO

APPENDIX 5

Journal Subscribed by the National Academy of Sciences, India, during
the year 1936.

GENERAL

Hirschwaldsche Buchhandlung,
Berlin, N. W. 7.

Die Natur-wissenschaften
24 Jahrgang

APPENDIX 6.

*List of papers read before the National Academy of Sciences, India,
during the period January 1st to 31st Decembsr, 1936.*

1. On the reconstruction of the Mass-defect curve and the stability of the Baryllium Isotpe Be₄, by Mr. N. K. Saha 7, Beli Road, Allahabad.
2. Studies of Ionosphere at Allahabad, by Messrs. G. R. Toshniwal, B. D. Pant, R.R. Bajpai, and B. K. Varma, Physics Deptt., Allahabad University.
3. Studies in the Respiration of Mango leaves, by Mr. N. K. Chatterji, M.Sc., Botany Deptt., Allahabad University.
4. Studies of Photochemical action in plant Respiration, by Dr. Shri Ranjan, D.Sc., Botany Deptt., Allahabad University.
5. Nitrogen fixation and Azotobacter count on the application of Molasses to the Soil in field, PART I., by Prof. N. R. Dhar and E. V. Seshacharyulu, Chemistry Deptt., Allahabad University.
6. Cytophysiological researches on the relation resistance of wheats to Puccinia glumarum Eriks and Henn., by Dr. G.T. Kale, Allahabad.
7. On the Saha-Srivastava Derivations of Ray light-Jeans Law, by Mr. Satyendra Ray, M.Sc., Lucknow University, Lucknow.
8. On the Phragman-Lindelof Principle, by Dr. P. L. Srivastava, Mathematics Deptt.. Allahabad University.
9. On the Convergence and the Summability of the Conjugate Series of the Derived Fourier Series, by Mr. K. L. Gupta, M.Sc., Mathematics Deptt.. Allahabad University.
10. The Photo reduction of Ferric Chloride in Alcoholic solutions in the light of a Quartz Mercury Vapour Lamp, by Messrs. Dr. Mata Prasad and B. V. Mohile, Chemistry Deptt., Royal Institute of Science, Bombay.
11. Sexual Dimorphism and post-embryonic growth in Dialedrodes dissimilis Quaint and Baker (Homoptera, Aleurodidae), by Dr. M. L. Roonwal, Ph.D., Zoology Deptt., Lucknow University, Lucknow.
12. A New Model Demountable Vacuum Furnace, by Prof. M. N. Saha, and Mr. A. N. Tandon, Physics Deptt., Allahabad University.

13. Studies on the Family Bucephalidae (Gasterostomata), PART II. Descriptions of Two New Forms from Indian Marine Fishes, by Mr. S. C. Varma, M.Sc., Zoology Deptt., Allahabad University.
14. Chemical Examination of the fruit of Physalis Peruviana or Cape Goose Berry, by Mr. Jagraj Behari Lal, M. Sc., Chemistry Deptt., Allahabad University.
15. Surface Tension of some Colloidal substances, by Mr. S. N. Banerji, Laboratories, Indian Drug House, Allahabad.
16. Formation of Periodic Precipitate in the absence of Foreign Gel, by Mr. R. N. Mittra, M.Sc., Chemistry Deptt., Allahabad University, Allahabad.
17. On a New Species of the Genus, Harmotrema Nicoll, 1914 with a position of the Genus, by Dr. H. R. Mehra, Ph. D., Zoology Deptt., Allahabad University, Allahabad.
18. Nitrogen fixation and Azotobacter count on the application of Sugars to the Soil, by Prof. N. R. Dhar and E. V. Seshacharyulu, Chemistry Deptt., Allahabad University.
19. Apparatus for the measurement of Respiratory Quotient in Plants, by Dr. Bholanath Singh and Prem Behari Mathur, Institute of Agricultural Research, Benares Hindu University, Benares.
20. Differentiation of a Definite integral with respect to a Parametr in certain cases when Leibnitz's rule is not applicable, by Mr. Uma Kant Shukla, M. Sc., Lucknow University, Lucknow.
21. An Anomaly in the Elastic Behaviour of Indian Rubber, by Mr. A. N. Puri, M.Sc., Hindu College, Delhi.
22. The Diazo-compounds of Morphine, by Mr. Amresh Chandra Roy, M.Sc., Biochemist, Imperial Institute of Veterinary Research, Muktesar.
23. A Note on the influence of Lyophilic colloide on the wettability of Napthaline, by Dr. A. C. Chatterji, D.Sc., Lucknow University, Lucknow.
24. The numerical value of Traube's Factor atom wettability data, by Dr. A.C. Chatterji, D.Sc., Chemistry Departmrnt, Lucknow University, Lucknow.

25. Chemical Examination of the Seeds of Physalis Peruviana or Cape Goose Berry, by Mahadeo Prasad Gupta and Jagraj Behari Lal, Chemistry Deptt., Allahabad University, Allahabad.
26. Chemical Examination of Oils from the Seed of (a) Crotalaria Medicaginea (b) Cassia Occidentalis, by R. K. Chatterji and S. Dutt, Chemistry Deptt., Allahabad University, Allahabad.
27. Dyes derived from 3: 4: 3': 4'—tetra-amido-diphenyl, by L. D. Tewari and S. Dutt, Chemistry Deptt., Allahabad University, Allahabad.
28. Constitution of fluoranthrenquinone and its derivatives, by B.B. Biswas and S. Dutt, Allahabad University, Allahabad.
29. Some observations of Sir Shah Sulaiman's Theories, by Mr. Zahur Husain, B.A., Government College, Lahore.
30. The Mathematical Theory of a New Relativity-Chapter XIII and XIV on the finite Velocity of Gravitation and the rotational Mechanics respectively, by The Hon'ble Sir Shah Muhammad Sulaiman, Kt., Chief Justice, High Court, 11, Edmonstone Road, Allahabad.
31. On Problems in Capillary Phenomena with Textile Fibres, by Late Mr. J. N. Sinha and Mr. Satyendra Ray, Upper India Couper Paper Mills and University of Lucknow.
32. Definition of Entropy through Probability, by Mr. Satyendra Ray, M.Sc. University of Lucknow, Lucknow.
33. On Evidences of Heisenberg Group Waves in the Continental Margin of Wegener's Drift Theory, by Mr. Satyendra Ray, M.Sc. University of Lucknow, Lucknow.
34. The Method of Parallax of Sulaiman, by Mr. Satyendra Ray, M.Sc., University of Lucknow, Lucknow.
35. The Direct Formation of Iodides and the distance of the closest approach of Atoms of Iodine, by Mr. Binayendra Nath Sen, Chemistry Deptt., Burdwan Raj College, Burdwan, (Bengal).
36. Theorems connecting different classes of Self-Reciprocal Functions, by Mr. R. V. Shastray, Benares Hindu University, Benares.
37. Curved Asymptotic Lines of ruled Surfaces, by Prof. Ram Behari, M.A., Ph.D., University of Delhi, Delhi,

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38. On the Statistical Interpretation of Entropy : A Criticism of Nernst, by Mr. Satyendra Ray, M.Sc., University of Lucknow, Lucknow.
 39. Alkali Soils and their reclamation, PART II., by Prof. N. R. Dhar and Mr. S. K. Mukerji, Chemistry Deptt., Allahabad University, Allahabad.
 40. Nitrogen in Soil fixation by Cellulosic materials Oils, Fats, etc. PART I., by Prof. N. R. Dhar and Mr. S. K. Mukerji, Chemistry Deptt., Allahabad University, Allahabad.
 41. The Chemical Examination of *Terminalia Arjuna* Bedd. PART II. Isolation of Arjunalin from the alcohoholic extract, by Mr. Radha Raman Agarwal, and S. Dutt, Chemistry Deptt., Allahabad University, Allahabad.
 42. Superposed Parasitism of *Cuscuta Reflexa* Roxb., by Dr. B. N. Singh and Mr. N.V. Saradhy, Institute of Agricultural Research, Benares Hindu University, Benares.
 43. Respiratory Response of Ripe Tomatoes and Dormant Potatoes following Wounding, by Dr. B.N. Singh and Mr. P.B. Mathur, Institute of Agricultural Research, Benares Hindu University, Benares.
 44. The Alimentary Canal of *Enilachua Indica* (Coccinellidae : Coleoptera) with a discussion on the activity of the mid-gut epithelium., by Mr. S. Pradhan, Deptt. of Zoology, Lucknow University, Lucknow.
 45. The Microscopic Anatomy and Haemology of the *Glares* and the *Os Penis* of the Common Indian Ground-Squierel (*Funambulus palmarum*), by Dr. M. A. H. Siddiqi, M.A., M.S., D. L. O., F.R.C.S., University of Lucknow (India), and H.E. LeMasurier, University of Toronto (Canada).
 46. Some Observations on Sir Shah Sulaiman's Theories II., Mr. Zahur Husain, B.A., Government College, Lahore.
 47. Is Rotational Motion merely Relative ?, by Mr. Zahur Husain, B.A., Government College, Lahore.
 48. Studies on the family Diplostomidae Poirier, 1886 (Syn. Alaridae Tubangui, 1922). PART I. "New Parasites of the genus *Bulbophorus* Dubois 1935, *Glossodiphlostomum* Dubois 1932, and *Neodiplostomoides* Gen. Nov.", by Mr. R. D. Vidyarthi, M.Sc., Zoology Deptt., Allahabad University, Allahabad.

49. Studies on the family Diplostomidae Poirier, 1886, PART II. Two New Parasites of the genus Diplostomum V. Nordmann., by Mr. R.D. Vidyarthi, M.Sc., Zoology Deptt., Allahabad University, Allahabad.
50. On the Amylase from the Indian water Chestnut (*Trapa bispinosa*, Roxb.), by Mr. Radha Raman Agarwal, M.Sc., Chemistry Deptt., Allahabad University, Allahabad.
51. On a simple derivation of Stresses in a moving Fluid., by Dr. R. N. Ghosh, D.Sc., Physics Deptt., Allahabad University, Allahabad.
52. The Prevention of Rots in Tomatoes with special reference to the Mould's attack., by Dr. B. N. Singh and G. P. Jakhanwal, Benares Hindu University, Benares.
53. Infra-red absorption spectrum of Tin-di-iodide., by Mr. L. S. Mathur, M.Sc., Physics Deptt.. Allahabad University, Allahabad.
54. Determination of Latent Leats of Vapourisation of the Selenides of Cadmium and Mercury and Telluride of Zinc from the absorption spectra of their vapours., by Mr. L. S. Mathur, M.Sc., Physics Deptt., Allahabad University, Allahabad.

Financial Statement of Receipt and Expenditure from 1st April to 31st December, 1936.

| Receipt. | Expenditure. |
|---|------------------------------|
| Opening Balance on 1st April 1936. | Rs. 30/- - 10/- 0. |
| Subscription from members. | 1,021 - 12/- 0. |
| Sale Proceeds of Proceedings of the National Academy of Sciences, India. | 55 - 1-0. |
| (Grant from the Imperial Council of Agricultural Research, New Delhi. | 500 - 0-0. |
| Donation. | 250 - 0-0. |
| Amount transferred from the Fixed Deposit to the Current Account. | 1,466 - 0-0. |
| Interest on Fixed Deposit for 1935-36. | 29 - 5-0. |
| Establishment Contingency. (Including printing, postage stamps, stationery, allowance etc.) | 246 - 2-9. |
| Printing of Proceedings of the Academy of Sciences, U. P. for 1935. | 550 - 12-0. |
| Printing of Proceedings of the National Academy of Sciences, India, for 1936. | 231 - 12-0. |
| Binding of journals. | 10 - 0-0. |
| Bank commission on outside cheques. | 8 - 8-0. |
| Purchased 17 Post Office 5-years' Cash Certificates of face value Rs. 100 at Rs. 88 1/2/- each. | Rs. 1,498 - 2-0. |
| Available Cash balance on 31st December, 1936, with the Imperial Bank of India. | 178 - 8-0. |
| Total Rupees 3,631 - 12 - 9. | Total Rupees 3,631 - 12 - 9. |
| H. R. Mehra, Ph. D. (Cantab), Hon. Treasurer, The National Academy of Sciences, India. | |